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ORIGINAL ARTICLES

DOES PHOTO-NITRIFICATION OCCUR IN THE SOIL?

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(Received for publication on 30 April 1947)

THE process of ammonification and nitrification, especially the latter, have been considered to be effected by the action of specific micro-organisms in the soil. This is evident from the fact that experimental work on nitrification has been carried out in different countries by placing the test soils or solutions in incubators or in laboratory rooms and in the absence of sunlight. Recently, Dhar and his collaborators [1933] have stated that ammonification and nitrification in soils, especially those in the tropics, are brought about more by photo-chemical than by bacterial agency. Some investigators have supported the contention while some have denied it. We have been investigating the validity of the claim that nitrification in the soil is mainly, if not entirely, a photo-chemical phenomenon and the results of our several experiments have not confirmed the findings of Dhar that the process is a photo-chemical one. On the other hand, our work strengthens the view that under normal soil conditions, light does not bring about nitrification but tends to do the reverse, namely, de-nitrification.

In the course of our investigations on nitrification in soils by keeping them in incubators or laboratory rooms, away from sunlight, we came across certain infertile soils which would not effect oxidation of organic or mineral nitrogen in the dark by biological agency. The non-occurrence of nitrification in such soils could be traced either to the absence of nitrifying organisms themselves or to the absence of favourable conditions (*e.g.* a proper base for neutralization, or a proper physical condition of the soil). These infertile soils, on exposure to sunlight, should show nitrification, if the new photo-chemical conception of the process is valid. In our experiments we used these and other normal soils to find out to what extent photo-chemical nitrification takes place and how it compares with nitrification occurring in darkness.

Experiments in pyrex glass vessels.

1. With Dacca soil

This soil, with a *p*H of 6·1, was known to contain nitrifying organisms and yet be incapable of oxidizing added nitrogen, in the form of oil-cakes or ammonium salts, and that the formation of nitrates in this soil, if occurred, on exposure to sunlight, could not be attributed to the biological factor.

After air-drying and passing through a 3 mm. sieve, the soil was divided into nine lots of 500 gms. each. All the lots were next transferred separately into previously sterilized 1,000 c.c. Erlenmeyer flasks plugged with cotton wool. The flasks containing the soil were then heated in an oven at 170°C. for one hour and allowed to cool. To three flasks out of the nine a sterile solution of ammonium sulphate, equivalent to one gram of dry salt per 100 gram of soil, was added and by a further addition of sterilized water the total moisture in the 500 gram of soil in each flask was made up to 189 c.c. Similarly a sterile solution of ammonium chloride, also at the rate of one gra of dry salt per 100 gram of soil with the necessary quantity of water (189 c.c. for 500 gram of soil in each flask) was added to three more flasks. To the third set of three flasks ammonium phosphate solution at the same rate of salt, soil and water as above, was added. Further treatment of the flasks was as follows:

One flask with each kind of ammonium salt was kept in the laboratory in the incubator as is usually done for testing nitrification of soils. One flask with each kind of salt was exposed to sunlight nearly eight hours per day. The total exposure to sunlight at the end of eight weeks was for 450 hours. The remaining three flasks with each kind of ammonium salt was first pasted with black paper used in packing photographic plates and then similarly exposed to sunlight along with the three flasks in the previous set. At the end of eight weeks, during which period the soils were not disturbed, as the moisture was sufficient, determinations were made of nitrites by the 'Griess-Ilosvay' method and of nitrate nitrogen by ' Phenol '-disulphonic acid method. The results are given in the following table :

TABLE I

Dacca soil with one per cent. ammonium salt and forty per cent. moisture all sterilized at 170°C (Results after eight weeks during which the concerned flasks were exposed to sunlight for 450 hours)

Treatment	Mgm. N per 100 gm. soil	
	Nitrite	Nitrate
Ammonium sulphate—		
Incubator kept	*nil*	1·2
Paper covered and exposed	,,	1·8
Sunlight exposed	,,	1·5
Ammonium chloride—		
Incubator kept	*nil*	1·8
Paper covered	,,	1·2
Sunlight exposed	,,	1·2
Ammonium phosphate—		
Incubator kept	*nil*	1·2
Paper covered	,,	1·8
Sunlight exposed	,,	1·5

The figures for ' nitrite and nitrate ' nitrogen in the table do not indicate any nitrification whatsoever with any of the salts. In the soil kept in the incubator there was no formation of nitrates and this was to be expected as the nitrifying organisms were already killed by heating the soil to 170°C. for one hour. Besides, the concentration of ammonium salts in the soil and the soil's reaction could not allow the biological agency to function properly.

The next experiment was with the same Dacca soil to which one per cent. calcium carbonate was added on the analogy of the biological process, in case, the photo-chemical one might require a base for the neutralization of the initial acid produced before further quantities of nitrates could be formed. The amounts of ammonium salts per 100 grams of soil remained the same as in the previous experiment. but the moisture content of the soil was maintained at 16 per cent. of the weight of the soil which is optimum for biological nitrification in the Dacca soil. The results are given in Table II.

TABLE II

Dacca soil 16 per cent. moisture and 1 per cent. lime ; soil not sterilized

Treatment	Mgm. N as NO_2 and NO_3 per 100 gm. soil			
	After one month		After eight weeks	
	NO_2	NO_3	NO_2	NO_3
Soil—$(NH_4)_2 SO_4$—				
Incubator kept	Traces	*nil*	0·02916	0·9
Paper covered	,,	,,	0·02916	0·3
Sunlight exposed	,,	,,	0·03888	0·9
Soil—NH_4Cl—				
Incubator kept	,,	,,	0·01944	1·2
Paper covered	,,	,,	0·03888	0·9
Sunlight exposed	,,	,,	0·03888	0·9
Soil—Ammonium phosphate—				
Incubator kept	,,	,,	0·4276	0·9
Paper covered	,,	,,	0·03888	0·9
Sunlight exposed	,,	,,	0·03888	0·9

There is again no photo-nitrification in the soil in the first month. After eight weeks the figures are the same for the exposed and covered flasks, both of which again have about the same values as for the biological nitrification in the incubator.

Effect of sunlight on nitrification in solutions

The effect of sunlight on nitrification in solutions was studied by adding one gram of the Dacca soil to flasks containing Omeliansky's solution, under sterile and non-sterile conditions.

TABLE III

Omeliansky's solution containing 10 mgm. nitrogen per 100 c.c. solution with 0·5 gm. $CaCO_3$ added in the form of sterile emulsion

One gram of Dacca soil added before and after sterilization as required

Treatment	N in milligrams per 100 c.c. solution					
	After one month		After six weeks		After eight weeks	
	NO_2	NO_3	NO_2	NO_3	NO_2	NO_3
Sterilized set—						
Incubator kept	Traces	*nil*	Traces	*nil*	Traces	*nil*
Duplicate	,,	,,	,,	,,	,,	,,
Paper covered	,,	,,	,,	,,	,,	,,
Duplicate	,,	,,	,,	,,	,,	,,
Sunlight exposed	,,	,,	,,	,,	,,	,,
Duplicate	,,	,,	,,	,,	,,	,,
Unsterilized set—						
Incubator kept	0·5832	1·2	Traces	6·0	Traces	6·3
Duplicate	0·1036	4·4	,,	7·2	,,	6·4
Paper covered	Traces	*nil*	1·296	*nil*	0·972	0·2
Duplicate	,,	,,	Traces	,,	0·02592	*nil*
Sunlight exposed	,,	,,	0·648	,,	0·486	0·2
Duplicate	,,	,,	Traces	,,	Traces	*nil*

The figures given in the above table show that in the 'sterilized soil set' no photo-nitrification is observed, while biological activity is impossible on account of destruction of any nitrifying flora that might have been present in the soil before sterilization.

From the results of the 'unsterilized soil set' we find that nitrifying organisms are present in the Dacca soil and are active as usual in the incubator kept flasks, but the activity of the nitrifying organisms is very much lessened in the flasks exposed to sunlight. Most of this effect is, in our opinion, due to heat, because flasks covered with black paper and left in sunlight show practically the same amount of nitrites as those exposed directly to the sunlight, there being only a slight excess of nitrogen oxidized in the paper covered flasks.

2. With Pusa soil

The soil of Pusa differs considerably from that of Dacca. It contains a large amount of lime (35 per cent. to 40 per cent. $CaCO_3$) and an active nitrifying flora, and its *p*H varies from 7·8 to 8·2. Under similar experimental details as with Dacca soil in experiment II, except that addition of lime was not made, the results shown below were observed.

TABLE IV

Pusa soil with 16 per cent. moisture and one per cent. ammonium salts

Treatment	Milligram N per 100 grams soil			
	After one month		After eight weeks	
	Nitrite	Nitrate	Nitrite	Nitrate
Ammonium sulphate—				
Incubator kept	0·583	0·75	0·7776	3·00
Paper covered	0·019	0·75	0·02916	0·75
Sunlight exposed	0·019	0·75	0·00972	0·75
Ammonium chloride—				
Incubator kept	0·039	0·75	0·00972	0·90
Paper covered	0·039	0·75	0·02916	0·90
Sunlight exposed	0·039	0·75	0·02916	0·90
Ammonium phosphate—				
Incubator kept	0·039	0·75	0·01944	0·90
Paper covered	0·039	0·75	0·01944	0·90
Sunlight exposed	0·039	0·75	0·00972	0·90

These figures again indicate that sunlight had practically no effect on transformation of nitrogen in ammonium salts into nitrates in Pusa soil also.

The effect of sunlight on nitrification in Omeliansky's solution was tested with this soil in the same manner as with Dacca soil. The results are given in Table V.

TABLE V

Omeliansky's solution—Pusa soil

Treatment	Milligrams N as NO_2, NO_3 in each flask					
	After six weeks		After eight weeks		After twelve weeks	
	NO_2	NO_3	NO_2	NO_3	NO_2	NO_3
Sterilized soil set—						
Incubator kept	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
Duplicate	,,	,,	,,	,,	,,	,,
Paper covered	,,	,,	,,	,,	,,	,,
Duplicate	,,	,,	,,	,,	,,	,,
Sunlight exposed	,,	,,	,,	,,	,,	,,
Duplicate	,,	,,	,,	,,	,,	,,
Unsterilized soil set—						
Incubator kept	*nil*	13·0	*nil*	15·0	*nil*	12·0
Duplicate	,,	13·0	,,	14·0	,,	12·5
Paper covered	1·62	Traces	,,	0·125	3·24	5·0
Duplicate	1·62	,,	,,	0·150	1·296	7·5
Sunlight exposed	0·1944	,,	,,	*nil*	Traces	*nil*
Duplicate	0·1944	,,	0·162	,,	*nil*	,,

The figures for 'nitrate nitrogen' in the unsterilized set clearly indicate that the nitrifying organisms, present in the soil, were as usual active in the dark, but when exposed to sunlight their power of converting ammoniacal nitrogen into nitrates was very much lessened. The amount of nitrate formed is insignificant in comparison with the nitrifying activity in the flasks pasted with black paper and similarly kept in the sun. In the sterilized soil set there was no photo-nitrification in any of the flasks as no nitrification could take place owing to the destruction of the biological agency by sterilization.

In these experiments for testing the effect of sunlight on nitrification, the amounts of nitrogen added were very large. The next set of experiments were with (*a*) the normal amounts used in our laboratory for testing biological nitrification and (*b*) the amounts used in field practice using ammonium salts, oilcakes and farmyard manure as sources of nitrogen. The results are given in the following table :

TABLE VI

Pusa soil and ammonium salts @ 30 mgm. N per 100 gram of untreated soil

Treatment	Mgm. N as NH_3, NO_2 and NO_3 per 100 gm. soil					
	After one month			After eight weeks		
	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3
Pusa soil and ammonium sulphate—						
Incubator kept	4·20	0·0388	30·0	4·20	0·0488	36·0
Paper covered	24·36	0·0388	0·3	14·28	0·0388	1·8
Sunlight exposed	26·04	0·0388	0·3	15·12	0·02916	1·5
Pusa soil and ammonium chloride—						
Incubator kept	3·36	0·0388	26·4	6·72	0·03888	28·8
Paper covered	28·56	0·0388	0·45	19·32	0·03888	1·8
Sunlight exposed	25·2	0·0388	0·45	20·16	0·03888	1·5
Pusa soil and ammonium phosphate—						
Incubator kept	5·04	0·0388	30·0	3·36	0·04860	36·0
Paper covered	26·88	0·0388	0·3	21·0	0·03888	1·8
Sunlight exposed	29·4	0·0388	0·3	18·48	0·0291	1·2

These results show, that with lower amounts of nitrogen added as in the experiment, the incubator kept soil converted nearly cent per cent. ammoniacal nitrogen into nitrates while the soil kept in the sun, whether covered with paper or not, effected hardly any change after one month. In other words, the biological nitrification process was rapid and certain while the photo-chemical activity was not evident within the first month. After eight weeks, the nitrate formation had begun in flasks kept in the sun, whether covered with paper or not, showing thereby that sunlight, as such, had not effected any appreciable increase in nitrates. The figures for the nitrification of farmyard manure and oil cake are given in the following Table VII:

TABLE VII

Pusa soil, oil cake and farmyard manure supplying different amounts of nitrogen

Treatment	Mgm. NO_3, NH_3 and NO_2											
	After two weeks			After four weeks			After eight weeks			After sixteen weeks		
	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3
Pusa soil and cake at 40 mgm. nitrogen per acre—												
Incubator kept	4·41	Traces	2·1	*nil*	*nil*	2·4	2·52	*nil*	5·4	3·36	*nil*	6·0
Paper covered	6·30	,,	1·2	3·18	,,	3·6	2·52	,,	6·0	3·36	,,	6·0
Sunlight exposed	6·30	,,	3·0	3·78	,,	2·4	4·20	,,	6·0	5·04	,,	6·0
Pusa soil and cake at 30 mgm. N. per 100 gm. soil—												
Incubator kept	6·93	,,	11·4	5·04	,,	13·2	4·20	,,	19·2	5·04	,,	19·2
Paper covered	6·30	,,	12·0	3·78	,,	13·2	7·56	,,	19·2	5·88	,,	24·0
Sunlight exposed	6·30	,,	10·8	3·78	,,	13·2	5·04	,,	19·2	5·04	,,	12·0
Pusa soil and farmyard manure at 10 tons per acre—												
Incubator kept	5·04	,,	1·8	2·52	,,	2·4	2·52	,,	5·4	1·68	,,	2·4
Paper covered	3·78	,,	2·4	3·78	,,	1·8	2·52	,,	6·0	3·36	,,	5·5
Sunlight exposed	6·30	,,	0·9	5·04	,,	1·2	3·36	,,	4·8	3·36	,,	1·8
Pusa soil and farmyard manure to supply 30 mgm. N per 100 gm. of soil—												
Incubator kept	7·56	,,	0·9	3·78	,,	2·4	5·04	,,	5·4	4·20	,,	3·6
Paper covered	6·30	,,	2·4	5·04	,,	3·0	1·68	,,	6·0	4·20	,,	4·2
Sunlight exposed	6·30	,,	1·5	5·04	,,	1·8	2·52	,,	6·0	4·20	,,	2·1

Initial NH_3 content = 3·36 mgm. per 100 gm. of soil
NO_2 = *nil.*
NO_3 = 0·9 ,, ,,

For the first eight weeks, the figures in the above Table show comparatively slight differences in the amounts of nitrates between samples of soil exposed to sunlight and kept in laboratory in-

cubators. These may be put down to experimental variation and hence are not of sufficient significance to support the hypothesis that photo-nitrification was taking place. Moreover, the temperature conditions for biological activity being favourable in flasks kept in the sun at the time of the year may also account for the result. This can be seen by comparing the incubator flasks with the black paper covered ones in the sun.

The table at any rate has given figures which may lead to some doubt and controversy between the supporters of the photo-nitrification theory and those who would try to explain the results on the accepted theory of bacterial nitrification. To set any doubts at rest, an exact duplicate of the above experiment, after sterilization of the soil together with the added amounts of nitrogenous materials, was carried out and the results given in the table below show that no nitrification had taken place in any of the flasks.

TABLE VIII

Pusa soil sterilized at 120°C. (autoclave)for 30 minutes after addition of 16 per cent. moisture and necessary quanitities of cake or farmyard manure

Treatment	Milligram N per 100 grams soil			
	After four weeks		After sixteen weeks	
	Nitrite	Nitrate	Nitrite	Nitrate
Pusa soil + Cake @ 40 lb. N per acre—				
Incubator kept	*nil*	0·9	*nil*	0·3
Paper covered	,,	0·9	,,	0·3
Sunlight exposed	,,	0·9	,,	0·3
Pusa soil + Cake @ 30 mgm. N per 100 gm. soil—				
Incubator kept	,,	0·8	,,	0·3
Paper covered	,,	0·6	,,	0·3
Sunlight exposed	,,	0·6	,,	0·2
Pusa soil + Farmyard manure @ 10 tons per acre—				
Incubator kept	,,	0·6	,,	0·3
Paper covered	,,	0·6	,,	0·3
Sunlight exposed	,,	0·6	,,	0·3
Pusa soil + Farmyard manure @ 30 mgm. N per 100 gm. soil—				
Incubator kept	,,	0·6	,,	0·3
Paper covered	,,	0·6	,,	0·3
Sunlight exposed	,,	0·6	,,	0·3

The next attempt was to see the effect of sunlight on ammonification of a peptone solution known to soil bacteriologists as Remy's solution, after the name of the investigator who first used it for measuring and comparing the ammonia produced by inoculating small quantities of soils into it. In one set the inoculated soil was sterilized, while, in the other, the soil was added without any previous treatment. Ammonia was determined by distillation with magnesia. The results obtained for each treatment of the flasks are recorded in Table IX.

TABLE IX

Ammonification of peptone in Remy's solution in flasks (50·4 mgm. nitrogen in each flask)

Treatment	Mgm N as NH_3 obtained by distillation with magnesia after			
	one day	two days	three days	five days
Sterile set—				
Incubator kept	0·56	0·56	0·56	0·56
Paper covered	0·56	0·70	0·56	0·56
Sunlight exposed	0·56	0·70	0·56	0·56
Unsterilized set—				
Incubator kept	9·56	22·12	27·16	30·52
Paper covered	10·50	24·64	26·88	31·08
Sunlight exposed	15·66	21·0	23·8	25·90

The amounts of ammonia in the sterile set have not increased in any of the flasks showing that sunlight had not effected ammonification. In the unsterilized set, the higher figures after the first day, relating to the flasks exposed to the sun, should be attributed to slightly favourable temperature conditions immediately after exposure to the sun. The advantage, if due to photo-chemical activity, was not maintained on subsequent days.

In the above experiments, special care had to be taken to avoid contamination of sterile flasks. It is well known to bacteriologists that imperfect sterilization or slight negligence in handling the flasks may occur at the hands of persons not thoroughly conversant with the technique. This may lead to contamination of media. If detected beforehand, the flasks containing the media are rejected. To determine how this may lead to erratic results, a number of peptone flasks, rejected because of suspected contamination, were used in one experiment and sterile soil added to it and the results are given in the following table:

TABLE IX (a)

Remy's solution imperfectly sterilized or badly handled

Treatment	Milligram N as NH_3 in each flask after			
	one day	two days	three days	five days
Incubator kept	5·32	0·7	7·56	No flask for determination
Paper covered	5·6	3·36	1·26	3·64
Sunlight exposed	1·68	7·28	4·48	1·12

These anomalous figures in the present experiment show production of ammonia in the supposed sterile flasks, while, as a matter of fact, the figures are due to some unnoticed contamination because as seen in Table IX, no ammonification takes place if sterilization is proper and a sterile condition is maintained.

As Dhar *et al* [1933] reported results of ammonification and nitrification with two per cent. urea solutions, we carried out a similar experiment using Pusa soil and in doing so, the sterilized solid urea was added to the solution containing the non-nitrogenous chemicals used in preparing Omeliansky's solution. Where the soil had to be sterilized, it was added to the solution containing the non-nitrogenous chemicals before autoclaving. The addition of urea was done in exactly the same manner as described by Dhar *et al* [1933]. The results are shown in Table X.

TABLE X

Treatment	Mgm. N as Nitrites and Nitrates after									
	two weeks		four weeks		six weeks		twelve weeks		twenty-four weeks	
	NO_2	NO_3	NO_2	NO_3	NO_2	NO_3	NO_2	NO_3	NO_2	NO_3
5 gm. Pusa soil and urea in a solution of potassium phosphate, magnesium sulphate and sodium chloride.										
A. Sterilized set—										
Incubator kept . .	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
Paper covered . .	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,
Sunlight exposed .	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,
B. Not sterilized set—										
Incubator kept . .	0·001296	,,	0·243	,,	0·162	,,	0·2592	,,	0·2592	,,
Paper covered . .	0·001296	,,	0·162	,,	0·162	,,	0·2592	,,	0·2592	,,
Sunlight exposed .	0·000972	,,	0·162	,,	0·0972	,,	0·0890	,,	0·0648	,,

The results show no conversion of urea into nitrite or nitrate when the soil was sterilized. Slight nitrite formation occurred, only when, the added soil was not sterilized showing that organisms contained in the soil were responsible for the results and not the photo-chemical effect of sunlight. The effect of sunlight is the reverse of what should be expected of the process of photo-nitrification.

Fraps and Sturges [1934] published the results of their investigations on photo-nitrification in soil. Like ourselves, they used *pyrex* glass flasks in their experiments, with results and conclusions practically the same as ours. Corbet [1935] criticized their work and stated that as *pyrex* vessels do not transmit ultra-violet rays, the experimental work was defective and the conlusions were wrong. Corbet evidently overlooked the fact that Dhar and Gopal Rao [1933] first reported that sunlight can effect the nitrification of ammonium sulphate in the soil from experiments carried out in *pyrex* glass vessels. We had, however, repeated our experiments in silica vessels side by side with glass vessels and with and without glass covers. The results are given in tables below.

TABLE XI

Effect of nitrification at different conditions of exposure to sunlight at 6 hours per day in Pusa soil mixed with different quantities of ammonium sulphate

	Mgm. N per 100 gm. soil found after twelve weeks	
	$-NO_2$	$-NO_3$
A		
Sterilized and containers *covered* with glass covers during and after exposure to sunlight—		
30 mgm. N per 100 gm. soil	0·01944	1·2
Duplicate	0·01944	1·8
1 gram ammonium sulphate per 100 gm. soil	0·01944	1·8
Duplicate	0·01944	1·8
B		
Sterilized but containers *open* during exposure to sunlight—		
30 mgm. N per 100 gm. soil	0·0486	1·5
Duplicate	0·0486	1·8
1 gm. ammonium sulphate per 100 gm. soil	0·0486	1·5
Duplicate	0·0486	1·5
C		
Not sterilized and not exposed to sunlight—		
30 mgm. N per 100 gm. soil	0·0583	21·6
1 gm. ammonium sulphate per 100 gm. soil	0·3888	3·0

It would appear from these results that exposure to sunlight either direct or through glass covers made no difference in the amounts of nitrite and nitrate nitrogen found even after twelve weeks. In the laboratory and in the absence of sunlight biological oxidation proceeded vigorously at lower concentrations of ammoniacal nitrogen, while at higher concentrations the process was retarded. This retardation due to high concentration of ammonium salts is well known to soil bacteriologists.

The next set of experiments were carried out in silica vessels.

TABLE XII

Effect of sunlight on oxidation of ammonium compounds In soil medium at the rate of one gm. in 100 gm. soil

Type of soil	Treatment	Kind of vessel used	Material added to the soil	Mgm. N per 100 gm. soil			
				Initially present		After six weeks	
				NO_2	NO_3	NO_2	NO_3
Dacca soil . .	Sterilized at 120°C.	Silica	Ammonium sulphate	Trace	1·2	*nil*	0·7
			Ammonium chloride	..	..	*nil*	1·2
			Ammonium phosphate	..	..	*nil*	1·2
Pusa soil . .	„	„	Ammonium sulphate	Trace	1·8	Used for exposure to ultra-violet rays	..
			Ammonium chloride	..	..	*nil*	0·9
			Ammonium phosphate	..	..	*nil*	1·2
Jorhat soil . .	„	„	Ammonium sulphate	..	..	*nil*	0·9
			Ammonium chloride	Trace	0·9	*nil*	0·9
			Ammonium phosphate	..	..	*nil*	1·2
Do. . .	„	Glass	Ammonium sulphate	..	..	*nil*	0·9
			Ammonium chloride	Trace	0·9	*nil*	1·2
			Ammonium phosphate	..	..	*nil*	0·9

These results show that with the high amounts of ammonium salts added to the soil, there was very little nitrification in them, even though there was every possibility of their contamination with nitrifying organisms during exposure.

An experiment by adding soil to Omeliansky solution and exposing it to sun was also performed. The composition of this solution is the most favourable for the nitrifying organisms and any contamination of the solution during exposure could be easily detected. The results are given in Table XIII below :

TABLE XIII

Effect of sunlight on oxidation of ammonium sulphate in liquid medium
(Omeliansky's solution)

Type of soil	Treatment	Vessel	Material added to	Mgm. N in original solution		N found after six weeks	
				NO_2	NO_3	NO_2	NO_3
Pusa	Sterilized and exposed to sun in open basin	Silica	100 c.c. Omeliansky solution and 1 gm. of soil	*nil*	*nil*	*nil*	*nil*
Jorhat	Ditto.	Do.	Ditto.	*nil*	*nil*	*nil*	*nil*
Dacca	Ditto.	Do.	Ditto.	*nil*	*nil*	*nil*	*nil*
Pusa	Sterilized and kept in the laboratory in open basin	Do.	Ditto.	*nil*	*nil*	*nil*	6·4
Jorhat	Ditto.	Do.	Ditto.	*nil*	*nil*	*nil*	0·6

These results again show that exposure to sunlight cannot effect oxidation of ammonium sulphate in Omeliansky solution. It should be noted that although the vessels were open to contamination during hours of exposure to sunlight, no oxidation due to biological agency appears to have taken place, whereas in the vessels kept in the laboratory, nitrification was evident. It appears, therefore, that sunlight, if it did anything at all, suppressed nitrification by the biological agents. We next turned our attention to the effect of the ultra-violet rays of the quartz mercury lamp on oxidation of ammonium sulphate in soil. A sample of the same Pusa soil which was tested for oxidation of ammonium salts in the quartz silica vessels was taken for the study. Its initial nitrogen as NO_2 was 0·01944 mgm. and nitrogen as NO_3 was 0·9 mgm. per 100 gm. of soil. To the soil was added one per cent. of its weight of ammonium sulphate and a layer of this mixture, one inch in thickness, was exposed to the rays of a quartz mercury lamp placed at a distance of 15 cm. from the soil. Nitrogen, as nitrite and nitrate, was determined at the end of three, eight, 12 and 16 hours exposure.

TABLE XIV

Effect of ultra-violet rays on oxidation of ammonium sulphate in solution
Mgm. N per 100 gm. of soil

Initial		After three hours		After eight hours		After 12 hours		After 16 hours	
NO_2	NO_3	NO_2	NO_3	NO_2	NO_3	NO_2	NO_3	NO_2	NO_3
0·01944	0·9	0·04860	0·9	0·04860	0·45	0·02916	*nil*	0·03888	*nil*

The figures in the table show that the nitrogen as nitrites, which increased over the initial after the first three hours' exposure, remained without any change up to eight hours' exposure but decreased after 12 hours' and after 16 hours' exposure there was a negligible increase over the 12 hours exposure. The nitrogen as nitrate, although remaining stationary after the first three hours' exposure, is reduced to 0·45 mgm. after eight hours' exposure and completely disappears after 12 and 16 hours' exposure.

The increase in nitrite nitrogen may be interpreted as the sign of oxidation of ammonium salts. It may as well be due to the reduction of a part of the nitrates. After eight hours' exposure to the ultra-violet rays, the nitrate nitrogen was reduced by 4·5 parts per million and after 12 and 16 hours' exposure there was no nitrate nitrogen and no further oxidation of ammonia had taken place during the period. It appears then, that beyond the increase after the first exposure, there is no sign of oxidation of ammonium sulphate in the soil.

In another experiment, Omeliansky's solution containing 10 mgm. N as ammonium sulphate per 100 c.c. was exposed in a quartz silica basin to the action of ultra-violet rays from quartz mercury vapour lamp placed at a distance of 15 cm. One gram of Pusa soil was added to the solution. The results are set out in the following table :

TABLE XV

Mgm. N per 100 c.c. solution as nitrites

Initial	After			
	Three hours	Eight hours	12 hours	16 hours
nil	0·01620	0·09072	0·07776	0·07776

Results—No nitrate was formed

During the third and eighth hours' exposure, nitrite was formed to the extent of 0·1 and 0·9 parts N per million. This amount decreased to 0·77 parts per million after 12 and 16 hours' exposure No nitrate was found at any time.

Till now, we have been considering experiments with different ammonium salts added to the soil and testing the effect of sunlight on them. The next set of experiments were with soil to which sodium nitrate was added. Ammonium phosphate and potassium phosphate were also used. One lot of soil receiving each of these salts was exposed to the sunlight and a duplicate was kept in the laboratory. Sufficient water was added to the soil to make an emulsion of the soil in each case, before exposure. The initial nitrogen content of the soil to which the several additions were made was as follows :

	Mgm. N per 100 gm. soil
NH_3	5·88
NO_2	Traces
NO_3	1·88

Sodium nitrate and ammonium phosphate were added to 50 gm. of soil to give 330 and 204·4 mgm. nitrogen respectively. After 12 hours' and 16 hours' exposure the usual determinations were made.

TABLE XVI

Treatment.	Milligrams N per 100 gm. of soil					
	After 12 hours			After 16 hours		
	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3
Pusa soil + water 300 per cent.—						
Exposed to sunlight	6·3	0·1944	*nil*	5·04	0·0486	*nil*
Kept in dark	5·04	0·0972	*nil*	6·30	0·0486	*nil*
Pusa soil + $NaNO_3$ 5 c.c. of a 20 per cent. solution water to make up to 200 per cent.—						
Exposed to sunlight	10·08	3·888	120·0	7·56	2·916	90·0
Kept in dark	7·56	1·1664	156·0	6·30	1·944	96·0
Pusa soil + ammonium phosphate one per cent. plus water—						
Exposed to sunlight	138·6	0·2332	0·9	83·16	0·2332	0·3
Kept in dark	159·5	0·0388	0·6	158	*nil*	0·3
Pusa soil + potassium phosphate one per cent. + water 300 per cent.—						
Exposed to sunlight	5·04	0·2332	0·9	3·78	0·2332	0·6
Kept in dark	10·08	0·1554	0·6	2·52	0·0777	0·3

These results show that the initial nitrates have decreased in all. The increase in ammoniacal nitrogen is less than 1 mgm. per 100 gm. soil in the control after 12 hours' exposure and a little more than 1 mgm. per 100 gm., in potassium phosphate added soil. The ammoniacal nitrogen is less than the amount added in the ammonium phosphate added soil, and more in the sodium nitrate added soil. The increase in N as nitrites is not more than two parts per million in all samples except the sodium nitrate added soil. The fact that the amount of 'nitrite nitrogen' found in the potassium phosphate added soil is the same as in the ammonium phosphate added soil, when both these lots of soil were exposed to the sun, suggests that the 'nitrite nitrogen' in the ammonium phosphate added soil was not necessarily derived from the oxidation of ammonium salts but might be, as well, derived from the reduction of nitrates and probably it was the presence of the phosphate radical that had something to do with the amount of 'nitrite nitrogen' rather than the ammonia radical. This observation, combined with the fact that nitrogen as nitrates decreased to some extent in all the soils and to a considerable extent in the sodium nitrate added soil shows that sunlight effects reduction of nitrates much more easily than it oxidizes the ammoniacal nitrogen to nitrites.

In these circumstances, it is doubtful whether the nitrites observed in the soil by Dhar and his colleagues should be called oxidation of ammonia or reduction of some of the nitrates from the soil to the nitrite stage.

The foregoing experiments were stated to test the hypothesis put forward by Dhar and others that nitrification in soil especially in tropical countries, is more a photo-chemical than a bacterial process. We have throughout our experiments seen no evidence of the activity of the sun's rays in promoting ammonification or nitrification : we are, therefore, naturally led to compare the conditions in our experiments and the methods used in our investigations with those of Dhar and his colleagues. There was not much difference in the conditions of experiments by the two schools of thought except that we had a biological control under the usual conditions. In the methods of determining nitrates

and nitrites, however, there is a difference. We have tested our methods for the determination of nitrites and nitrates time and again and have found them giving concordant results unless chlorides were present in large quantities, when we used the aluminium method for determining nitrates. The method for determining nitrites has not given us any trouble. We have tested that with the concentration of the ammonium salts used in our experiments, the nitrates and nitrites, had they been present in any large amounts could have given the proper tint ; and hence, we can assert that absence or low amounts of nitrates or nitrites in our experiments are not due to any influence of concentration of ammonium salts or any defect in our method. We have tried to avoid contamination in our experiments, as far as possible, especially in the sterilized set while we have provided an unsterilized set wherever very high concentrations of ammonium salts could prevent nitrification in the early weeks.

We think that the provision of a control for the usual biological process in the incubator and methods of independent determinations are a necessity for the just assessment of the existence of the photo-nitrification process. The fact that we get a negative result in ammonification shows that perhaps contamination owing to want of proper technique has been a factor which has influenced the results obtained by Dhar and his colleagues.

If photo-nitrification in soil could be brought about and controlled by man, it would be of great help to the cultivators of those soils which owe their infertility to causes connected with the improper working of the biological agency of nitrification, but unfortunately from our experiments we are led to the conclusion that photo-nitrification is not at all a regular process and there is doubt whether it exists. Even if it is in evidence anywhere, it is so microscopic that there is no prospect of its proving helpful to the agriculturist in his problems in the near future.

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THE FERROUS IRON CONTENTS OF INDIAN SOILS

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IT has been definitely established that deficiency of iron intake leads to nutritional and hypochromic anaemias in man, with consequent loss of health and economic efficiency. Generally, we get our normal requirement of iron from foodstuffs, the major part of which is derived from vegetable sources. The iron contents of these food materials of plant origin are again obtained from the soil on which the plants are grown. The influence of the iron content of the soil on the health of animals living on the area has been brought out by an observation of Archibald and *et al* [1938] in the U. S. A. It was found that in Southern Massachussetts the cattle suffered from nutritional anaemia which could be traced to an insufficient amount of iron in the forage, which in its turn was due to a very low iron content in the soils on which the forage was grown, and further that the subsequent addition of iron to that soil resulted in a large increase of iron in the forage.

Iron in the soil is generally present in the ferric condition, but this is reduced to the ferrous form during various chemical and biochemical processes occurring in the soil. It is now known [Kliman, 1937] that only the ferrous iron can be absorbed and utilized by plants, and this therefore represents the available iron. But the total and specially the ferric iron content is also significant representing as it does the potential source of ferrous iron. A knowledge of both the total and ferrous iron contents of any soil should therefore be valuable as a guide to the level of iron contents of food crops and other vegetable matter grown on it.

In view of its importance in relation to the health and economy of the country it was considered desirable to make a study of the total and ferrous iron contents of Indian soils from different places. In the present work such determinations have been made on three soil samples collected locally and on 18 samples from the various soil Research Stations in different parts of India, obtained through the courtesy of Rao Bahadur B. Viswanath, F.R.I.C., Director of the Imperial Agricultural Research Institute, at the time.

Experimental

Soil samples : These were air-dried and passed through a 20 mesh sieve, and only the finer fraction was taken for analysis.

Analysis : Moisture was estimated by heating 2 gm. of soil at 105°C. to constant weight.

For total iron estimation, 2 gm. of the soil was carefully ignited in an open platinum crucible for five hours, and was then alternately digested with hydrochloric acid and evaporated on water bath, repeating the process four times. The residue was taken in dilute hydrochloric acid, filtered and the filtrate made up to a known volume. Finally, an aliquot part of the filtrate was titrated against standard titanous chloride solution, using ammonium thiocyanate as indicator.

For the determination of ferrous iron, 15 gm. of the soil was macerated with 150 c.c. of 2 per cent. aluminium chloride solution and kept in the dark, and 10 c.c. of the supernatant liquid was taken at intervals of one week or more for analysis. The actual estimation was done by the dipyridyl method [Hill, 1930 ; Kohler, 1936 ; Goswami and Basu, 1938]. 10 c.c. of the clear supernatant liquid was pipetted from near the surface to an Erlermeyer flask containing 10 c.c. of phthalate buffer solution of *p*H 5·8 and a trace of hydro-quinone and 5 c.c. of a 0·2 per cent. solution of $\alpha.\alpha^1$. dipyridyl in acetic acid (5 per cent.) were added to it. The flask was set aside in the dark for half an hour and then compared with a standard in a Klett biocolorimeter. A blank determination was similarly made without using the soil, and this was allowed for in arriving at the true result. The hydroquinone was added in order to retard the aerial oxidation of ferrous iron in the test solution.

The standard was obtained by adding 1 c.c. of a stock solution of M/100 ferrous iron, prepared by disolving 0·392 gm. of ferrous ammonium sulphate (analytical reagent quality) in 100 c.c. to 5 c.c. of 0·2 per cent. dipyridyl solution in acetic acid (5 per cent.) and making up the volume to 250 c.c. with water after the addition of 0·2 gm. of hydroquinone.

The results are given in Table I.

TABLE I

Total and ferrous iron contents of soils

Soil	Moisture per cent.	Total iron per cent.	Ferrous iron (mg. per cent.) determined after weeks				
			1st	2nd	3rd	4th	7th
Baranagar 9 in.—12 in. cultivated No. I	8·65	2·58	1·05	3·56	4·48	5·43	5·84
Ditto. No. II . .	12·31	2·14	0·23	2·88	3·41	4·26	4·89
Ditto No. III . .	10·26	3·02	0·68	2·56	4·25	4·88	5·12
Wraseoni, C. P., cultivated, 0—9 in..	2·52	2·60	0·301	0·709	0·739	0·810	0·911
Rangpur farm, cultivated, unmanured 0—9 in.	0·97	3·60	15·00	25·00	17·80	5·75	2·18
Kanke (Bihar)	1·30	2·06	0·432	0·732	0·739	0·739	0·214
Shahjahanpur, U. P., light loam, 0—9 in.	0·65	1·21	*nil*	*nil*	*nil*	*nil*	*nil*
Sakrand (sweet land) Sind . .	1·20	3·06	0·82	1·33	1·35	1·10	1·05
Kharua, C. I., Unirrigated, 0—9 in. .	5·10	4·64	*nil*	*nil*	*nil*	*nil*	*nil*
Berampur (Orissa)	1·18	2·16	1·23	6·915	23·31	28·65	28·00
Sabour (Bihar)	1·13	1·40	0·132	0·275	0·150	0·015	0·130
Nagpur Farm, C. P., cultivated .	6·80	5·60	*nil*	*nil*	*nil*	*nil*	*nil*
Anakapalle (Madras), cultivated, unmanured 0—9 in.	1·25	3·15	*nil*	*nil*	*nil*	*nil*	*nil*
Belgaon (Bombay)	5·40	13·56	*nil*	*nil*	*nil*	*nil*	*nil*
Tarriab Farm, Peshawar . . .	1·04	3·27	1·20	2·30	2·010	2·010	2·010
Chand Khuri (C.P.) . . .	3·40	9·50	*nil*	*nil*	*nil*	*nil*	*nil*
Lahore	1·04	3·05	*nil*	*nil*	*nil*	*nil*	*nil*
Coimbatore (Madras) . . .	1·60	2·01	0·403	0·946	0·900	0·900	0·900
Nandyal (Madras)	6·09	4·70	*nil*	*nil*	*nil*	*nil*	*nil*
Tabiji, Ajmere Merwara . . .	0·33	0·86	*nil*	*nil*	*nil*	*nil*	*nil*
Aligarh Farm	1·14	2·48	*nil*	*nil*	*nil*	*nil*	*nil*

Discussion and conclusion

The ferrous iron in the soil is present almost exclusively in the exchangeable form and can be brought into the solution phase by treatment with aluminium chloride [Ignatieff, 1941]. But the gradual increase in the ferrous iron content of the supernatant liquid shows that this replacement is a slow process, which made it necessary to keep the soil in contact with the solution for weeks together. But in some cases the observed ferrous iron content also showed a decrease with time indicating that oxidation of the ferrous iron took place on prolonged storage in spite of the addition of hydroquinone. The maximum value obtained for each soil would therefore represent a more reliable measure of its ferrous iron content.

It was observed by Ignatieff [1941] that grey wooded and black soils contain not more than 0·2 to 0·3 mg. per cent. of ferrous iron to a depth of about 2 ft., and that its concentration is much higher in a peat bog. The present work shows that while in some of the Indian soils the ferrous iron content is fairly high, it is totally absent in several of them. Further, there are wide variations in the total iron contents also.

In view of the above observations, it should prove of great interest if systematic investigations are undertaken for determining the total and ferrous iron contents in various parts of our country and in different seasons and attempts are made for correlating such data with the iron contents of the food crops and forage and the health of the human and cattle population of the respective areas.

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RESPONSE OF SUDAN GRASS TO SOME AGRONOMIC FACTORS

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NO DOUBT, *Jowar* (*Andropogon sorghum*) is the premier fodder crop of the Punjab, both in the irrigated and *barani* (rain-fed) areas, and can be cultivated throughout the summer season, but it would increase much more in its value if it were possible to secure from it a number of cuttings of green-fodder like berseem (*Trifolium alexandrinum*) in winter. Moreover, *Jowar* is highly susceptible to the attack of borer, which causes great deterioration both in quality and quantity of its fodder. Recognizing these facts a systematic search was conducted to find a crop, suitable for the Punjab, which would not only give a number of cuttings of green fodder during summer, but would also be less susceptible to the attack of borer. A small sample of Sudan grass (*Andropogon sorghum X Var-sudanensis*), obtained from the Department of Agriculture, Australia, about two decades ago [Milne-*et al* 1934], promised to fulfil both these requirements to a great extent. A portion of the seed was sown at the Fodder Research Station, and small quantities were tried with some of the interested growers in the Punjab. The results were very encouraging. It was observed that the grass adapted itself admirably to the climatic conditions prevailing here.

Under rich land conditions and heavy irrigation, sudan grass appeared to be a very satisfactory forage crop for the summer season. It was superior to *jowar* because of the comparatively wide range of season, in which it could be cultivated. Sown in March, unlike *Jowar*, it gave a number of cuttings of green fodder during the growing season. Early sown crop was ready in May, that is, in about two months, at a time when the farmers experienced a great shortage of green fodder because of the drying up of berseem. Further it continued to give cuttings of green fodder till October, November, *i.e.*, second period of fodder scarcity in the year.

As sudan grass gained great popularity and was found to be a very useful addition to the crop husbandry of the Province, it was recommended for cultivation by the Department of Agriculture, Punjab, Saini [1931]. The details regarding the methods of cultivation and the advantages of including it in the farm economy of the Province, were published Saini [1937].

The preliminary experiments, conducted hitherto, under varying soil and climatic conditions, provided information as to the suitability and importance of the crop, but exact knowledge, as to how the crop responded to various agronomic factors such as the best stage of cutting, the optimum requirements of irrigation and manures, based on systematic experiments, was very limited. Although some experiments regarding the management of other grasses have been reported in the literature, under a system of repeated cuttings, studies on sudan grass have been very few. The present investigation was, therefore, undertaken to find out the influence of some of the undermentioned agronomic factors on the yield and quality of sudan grass, at the Fodder Research Station, Sirsa.

(i) The most suitable interval between two successive cuttings.
(ii) Optimum irrigation to secure maximum yield of forage.
(iii) Influence of varying quantities of farmyard manure on the outturn of green fodder.
(iv) Effect of these factors on the chemical composition and quality of the grass.

Review of literature

Vinall [1920] reported the results of cutting sudan grass at varying stages of growth at the experiment station, Hays, Kans. He concluded that it was profitable to cut the grass before it began to ear, but preferable stage of maturity for cutting was from the time it began earing until it was fully headed. He further states that there was little loss when the grass was allowed to grow until the seed had reached the soft dough stage, when it would give the highest yield in one cutting.

A number of investigations carried out under varying soil and climatic conditions reported hitherto, provided information relative to the increase in yield by the use of complete fertilizers. Ahlgren [1938] summarized some of the data of such experiments, and indicated that marked responses might be obtained by the use of commercial fertilizers on soils which are deficient in fertility. He further adduced conclusive evidence to show that forage cut or grazed closely and frequently resulted in reduced yields, but Garber *et al* [1927] found that, where 22 close cuttings with a lawn mower did not kill kentucky blue grass, only nine cuttings of lucerne resulted in death to nearly all plants.

Material and methods

The experiment, reported herein, was conducted for a period of two years 1942-44 at the Fodder Research Station, Sirsa, which is situated in the South East Punjab. Though average rainfall of the tract varies from 10 in.—12 in. per annum, most of it is received during the summer months of July and August. The soil of the station on the whole is a fertile medium loam, but ranges from light sandy to heavy clay, and is irrigated by a perennial canal.

The experiments in the two seasons were conducted on light and medium types of loamy soils in two fields, which differed to some extent in their physical texture and levels of fertility. They were designed to include three variables of each of the three treatments :

(i) *Farmyard manure.* This is most easily procurable and the most complete fertilizer available at the farm. The variables, viz., no manure, light manuring and heavy manuring were included to enable a comparison of the light and heavy manuring versus no manure, on the yield of grass as is indicated below :

(*a*) M1 . . . No manure.
(*b*) M2 . . Light manure at the rate of 14 tons or 375 md. per acre.
(*c*) M3 . . Heavy manure at the rate of 28 tons or 750 md. per acre.

(ii) Given optimum conditions of growth, forage crops would yield the highest if supplied with an abundance of irrigation water. Three levels of irrigation were taken to represent :

(*a*) Optimum irrigation watering after every two weeks.
(*b*) High irrigation watering after every one week.
(*c*) Low irrigation watering after every three weeks.

(iii) Sudan grass is capable of giving a number of cuttings of green fodder, but the best stage and interval between two cuttings, with a view to secure maximum yield, was determined by fixing arbitrarily three intervals, viz. :

(*a*) Cutting after every 30 days.
(*b*) Cutting after every 40 days.
(*c*) Cutting after every 50 days.

Each of these intervals indicated a definite stage of growth of the plant. In the first type, the crop was cut when it was young and nearing heading stage. The second interval, of 40 days was designed to find the effect of cutting when the crop was in full bloom stage, and some of the panicles were yet emerging out of the sheaths. The third cutting variable of 50 days indicated the comparative effect of permitting the grass to make an uninterrupted growth to a late heading stage when grain had reached the soft dough stage.

Fig. 1

The crop was sown on 23 May 1943 in unit sub-plots of 1/50th acre in a two-acre field. The sowing was done on 8 May 1943, a fortnight earlier in unit sub-plots of 1/100th acre next year. Ten seers seed per acre were used in both cases.

Farmyard manure was applied to the fields about a month before sowing, in order to mix it well in the soil before the sowing of the crop was carried out.

The cuttings of the grass in different plots were taken according to the schedule on the fixed dates.

Season

The two crop seasons varied a great deal in the two years as is indicated by the monthly rainfall data.

Month	Rainfall in inches	
	1942-43	1943-44
May	....	0·13 in 1 shower
June	0·68 in 3 showers	1·32 in 5 showers
July	3·09 in 7 showers	1·99 in 5 showers
August	3·98 in 11 showers	0·47 in 2 showers
September	4·36 in 9 showers	2·53 in 4 showers
October	....	....
November	....	....
Total	12·09 in 30 showers	6·44 in 17 showers

It will be observed that, while most of the rainfall was received in July, August, in both the crop seasons, it varied a great deal from one month to another. The total rainfall of 12·09 in. in 30 showers in the year 1942-43 was almost double the 6·44 in. in 17 showers in 1943-44. Because of the comparatively high rainfall in the former marked variation in yield of forage was noticed. The crop in the first season though it made fair growth, was adversely influenced by excessive moisture, due to frequent showers, of rain, during its growing period. As a result the crop was badly damaged by red-leaf spot, and did not attain full growth either in height or tillering during the rainy months.

The supply of water in the canal remained regular, and enabled the schedule of irrigation intervals to be followed fairly closely, but the high rainfall in the year 1942-43 equalized some of the influence of high and low levels of irrigation.

Results and discussion

The analysis of variance, used in evaluating the data with regard to yield of green fodder under a system of repeated cuttings at varying intervals, different doses of farmyard manure, and three intensities of irrigation, are given in Table I.

Table I

Analysis of variance of the yield data in the two experiments 1942-43 and 1943-44

Due to	D.F.	1942-43			1943-44		
		S.S.	M.S.	F.	S.S.	M.S.	F.
Blocks	1	28,336·5	28,336·5	11·73	337·5	337·5	..
Times	2	52,718	26,359·1	10·91*	23,601·4	11,800·7	17·94*
Irrigations	2	22,156·3	11,078·2	4·58*	33,452·1	16,726·5	25·82*
Manures	2	9,842·5	4,921·3	2·03‡	31,036·8	15,718·4	23·59*
Times × Irrigation	4	4,231·0	1,057·8	..	3,761·2	9,140·3	1·4‡
Times × Manures	4	5,937·2	1·484·3	..	2,638·2	659·5	1·0‡
Irrigation × Manures	4	10,063·0	2,515·8	1·04‡	1,451·8	362·9	‡
Times × Irrigations × Manures	8	35,519·7	4,439·9	1·83‡	12,245·9	1,530·7	2·32†
Error	26	62,777·0	62,777·0	..	657·76	..	..
Total	53	231,581·3	..	..	125,626·1	..	..
Critical difference at 5 per cent.	42·1 md.			44·0 md.			
Critical difference at 1 per cent.	56·9 md.			59·3 md.			

* Significant at 1 per cent.
† Significant at 5 per cent.
‡ Not significant

Effect of varying intervals of cutting on the yield of sudan grass

With a view to find out the effect of varying intervals of cutting on the yield of sudan grass, and to find out the most appropriate and economical interval and suitable stage of cutting, a definite cutting schedule was adopted for harvesting the crop. The dates and the number of cuttings taken during the course of the experiment in the two years are shown below in Table II.

TABLE II

Dates and number of cuttings under varying intervals in 1942-43 and 1943-44
(*Intervals between two cuttings in days*)

No. of cuttings	30 days		40 days		50 days		Remarks
	1942-43	1943-44	1942-43	1943-44	1942-43	1943-44	
1	22-6-42	7-6-42	2-7-42	17-6-43	12-7-42	27-6-43	
2	22-7-42	7-7-43	11-8-42	27-7-43	31-8-42	16-8-43	
3	22-8-42	6-8-43	20-9-42	5-9-43	20-10-42	5-10-43	
4	22-9-42	5-9-43	30-9-42	15-10-43	..	24-11-43	
5	22-10-42	5-10-43	..	24-11-43	..	..	
6	..	5-11-43	..	..	..	..	
Total No. of cuttings	5	6	4	5	3	4	

It will be seen from the above that in all the cases of varying intervals between two cuttings, one more cutting was taken in 1943-44 than in 1942-43, due to the sowing having been done a fortnight earlier in the second experiment. In all, five cuttings were obtained in 30 days' interval in 1942 and six in the second season. Similarly, five cuttings were taken in 1943 in comparison to four obtained in the year 1942, in the second cutting variable, and four in comparison to three cuttings in the third cutting treatment of 50 days' interval in the second season as compared to the first.

The total yields of green fodder per acre, after eliminating the block effect, given in Table III, below showed wide variations in the outturns obtained under various treatments in the two successive experiments. The minimum difference, required for significance at 5 per cent. level, was found to be 33·7 and 17·6 seers per unit sub-plot or 42·1 and 44·0 maunds per acre in the two experiments. When these values were used as tests of significance, the yields of forage, produced in 1942-43 and 1943-44 by the 40 and 50 days' cutting intervals, that is, when the crop had either reached its full heading stage or had advanced in the stage of maturity, and had reached the soft dough stage, were significantly higher than those obtained from cuttings taken at intervals of 30 days. The difference in yield between the former two was not great enough to be of any significance, but the trend was in favour of the 40 days' interval in the year 1942-43 and of 50 days' interval in the year 1943-44.

TABLE III

Yield of sudan grass per acre in maunds under varying intervals between two cuttings and under various fertilizer and irrigation treatments

Year	Cutting interval	Manurial Treatment									Mean yield		
		Nil			375 md.			750 md.					
		Irrigation			Irrigation			Irrigation					
		2 weeks	1 week	3 weeks	2 weeks	1 week	3 weeks	2 weeks	1 week	3 weeks			
1942-43	30 days	603	480	478	515	613	556	570	627	480	547	—	..
	40 days	643	667	575	593	721	639	663	593	616	634	+	87
	50 days	549	603	593	650	632	632	622	753	604	626	—	8
1943-44	30 days	621	637	581	658	801	602	847	847	720	702	—	..
	40 days	724	834	639	758	916	668	873	928	703	783	+	81
	50 days	810	828	600	817	867	874	802	962	900	829	+	46

Sudan grass attained sufficient growth in 30 days, so much so, that it approached earing, and was cut for forage. Most of the ears were completely out of the sheath in the second treatment of 40 days' interval, and plants reached advanced stage of maturity in the third treatment of 50 days' interval. The yields, given in the Table III above, showed conclusively that intervals of 40 days and 50 days between two cuttings were better than the 30 days' cutting interval. From the column of mean yields it will be noticed that 547 and 702 maunds per acre were obtained in the 30 days' interval, 634 maunds and 783 maunds per acre in the 40 days' interval, and 626 maunds and 829 maunds per acre in the 50 days' interval in the two experiments during 1942-43 and 1943-44 respectively.

The yield of sudan grass was significantly less in the case of 30 days' interval, as compared to the 40 days' and 50 days' interval. However, the difference in the yields in the case of 40 days' and 50 days' interval were not significant. From these results it was concluded that the second treatment of 40 days'interval was superior to the other two treatments, both in the quantity of green stuff and in the number of cuttings : and that the best stage was when most of the ears were completely out of the sheath, or a little later when the grain had been formed. The total yield was slightly less in the third treatment in three cuttings than in the second treatment in four cuttings in 1942-43, but a slight though insignificant increase was noticed in favour of the third treatment in 1943-44. The second treatment of 40 days' cutting interval was better than others, because it allowed a fairly good number of cuttings to be secured from the crop during the growing season. These results agreed closely with those of Vinall [1920] and Piper [1937], who reported that it was not profitable to cut sudan grass before it started heading, and who obtained high yields from the crop from the time it began to ear until it was fully headed. They also observed some increase in yield, if the grass was allowed to grow until the seed had reached the soft dough stage. Though there were insignificant differences in the yields of the grass when cut at either 40 or 50 days' interval, the number of cuttings was definitely reduced in the latter. The conclusion was, therefore drawn, that the second treatment of 40 days' interval was preferable.

Variation in yields of individual cuttings of sudan grass as influenced by different stages of growth

The total yields of sudan grass have been found to vary a great deal according to the interval between two cuttings. As mentioned above, they were the lowest when the crop was cut very

frequently at intervals of 30 days, and were the highest when this interval was increased to 40 or 50 days, but the number of cuttings was the maximum in case interval was the shortest. The yields of green fodder in individual cuttings in the three cutting treatments showed marked variation, as is shown in Table IV below :

Table IV

Showing the average yield per acre in maunds from individual cuttings of Sudan grass in the three cutting treatments

	Cutting interval	No. of cuttings	1942	1943	Mean yield
1	30 days	1	53·1	43·2	48·1
		2	130·7	311·0	220·8
		3	181·2	189·5	185·3
		4	32·5	68·2	50·3
		5	23·1	53·7	38·4
		6	..	32·7	32·7
2	40 days	1	187·5	191·3	189·5
		2	344·4	355·2	349·8
		3	58·7	130·2	94·4
		4	48·5	85·0	66·8
		5	..	23·0	23·0
3	50 days	1	285·0	344·2	314·6
		2	281·0	318·0	299·5
		3	64·0	128·5	96·2
		4	..	43·8	43·8

It will be observed from the Table IV that in the 30 days' cutting treatment, very low yields were obtained in the first cutting. The yields increased in the second and third cuttings because of the plants having by that time established themselves well, and the season having become favourable for the growth of the crop due to showers of rain. The yields were reduced considerably in the cuttings taken after this period.

As regards 40 days' interval, higher yields were secured in the first cutting than the same cutting in the 30 days' cutting treatment, but the highest yield was secured in the second cutting, after which a great decline was observed in the quantity of forage produced.

In the third cutting treatment of 50 days' interval, the highest yields were obtained in the first cutting. The outturn was high in the second cutting, after which it was reduced to a great extent.

Table IV further shows the influence of soil, season and sowing time on the yield of the crop in the two years. Except in the first cutting in the first treatment, they are almost double in 1943-44 ; similarly they were higher in the other two treatments. The crop in the second experiment was sown

on a comparatively more fertile soil about a fortnight earlier than the crop in 1942-43. Further it received only moderate amount of rainfall during its growing period as compared to the crop in the first experiments, when heavy rainfall influenced the growth rather adversely.

From the average yields given in the last column, it is evident that, while 48 maunds per acre of green fodder was obtained from the first cutting in the 30 days' cutting treatment, yields of 189 and 314 maunds per acre were obtained in the first cutting in the other two treatments, viz., 40 and 50 days' intervals respectively. The yields in the second cutting were fairly heavy, 220 maunds, in the first treatment, and 349·8 and 299·5 maunds in the other two treatments. The quantity of green stuff was reduced in other cuttings in all the three treatments, but was higher in the third cutting in the 30 days' cutting treatment. The differences in the outturns in the first and second cuttings were very marked, and were due to the fact that the crop to start with had less number of tillers, and they too in the young stage of growth. The crop made good growth in the other two cutting treatments, which accounted for the heavier yields.

The results further pointed out that vigour of growth of the crop was exhausted after two or three cuttings, and that the plants were hardly able to attain their normal growth, both as regards optimum height and development of tillers. The yields were therefore, low in the rest of the cuttings. It, however, matters little, if the yields are to some extent low to start with in May and June or at the end of the growing season in October, November, because acute fodder shortage is experienced at those periods of the year in the irrigated areas of the Province [Saini 1937]. Berseem (*Trifolium alexandrinum*), which carries the stock over the winter season, is almost dry and over in May, and is either sown or is very young in October, and practically no other green fodder is available. The importance of sudan grass thus lies in supplying green fodder during these scarcity periods. Yields is a secondary consideration then.

Effect of farmyard manure and irrigation on the yield of the grass

The analysis of variance given in Table I, and summary of the yields of green fodder given in Table III, indicated the increase in productivity due to different doses of manure. The differences were highly significant in 1943-44 and non-significant in 1942-43, due to excessive rains as stated above. The comparison of the effects of different doses of farmyard manure in 1943-44 is shown below :

Effect of different doses of farmyard manure during 1943-44 yield in maunds per acre

Dose	Yield	Significance of result
1. High 750 md. per acre	841·7	M3>M2>M1
2. Medium 375 md. per acre	767·5	
3. No manure (control)	695·0	

That the productivity of the grass was influenced by the quantity of irrigation water available was also evident from the Tables referred to above. The differences in outturns due to the intensities of irrigation were significant in 1942-43 and highly significant in 1943-44. The comparative yields of grass as influenced by different intervals of irrigation are given below :

Yield of grass under different intervals of irrigation

Year	High (1 week)	Medium (2 weeks)	Low (3 weeks)	Significance of result
1942-43	633·0	601·2	571·0	High > Mdm. > low
1943-44	845·5	765·7	693·2	High > Mdm. > low

The figures given above show conclusively the effect of irrigation intensity on the yield of grass. Maximum yields were obtained under high level of irrigation in both the experiments. The differences between medium and low levels were insignificant in the year 1942-43, due to excessive and large number of showers. In the second experiment, not only yields were higher than those obtained in the first, but the differences were very marked, 845·5 maunds having been obtained under frequent irrigation applied at weekly intervals. They were reduced to 765·7 maunds as the interval was increased to two weeks, and still lower yields were obtained as the interval was increased to three weeks, or frequency of irrigation was reduced.

The interaction of manures and irrigations in the two experiments is shown below :

TABLE V

Year	Interval of irrigations	Manures			Significance of result
		Nil	375 md.	750 md.	
1942-43	One week	583·0	655·0	658·0	±17·1
	Two weeks	598·0	586·0	618·0	
	Three weeks	582·0	609·0	567·0	
1943-44	One week	770·0	861·0	912·0	±25·4
	Two weeks	718·0	744·0	841·0	
	Three weeks	607·0	715·0	774·0	

From the data presented above, it was apparent that the high level of irrigation with manure was better than no manuring in the year 1942-43, while the high level of irrigation with heavy dose of manure was significantly superior to other levels. It was closely followed by the lower dose of manure and irrigation, but insignificant differences, between high and low levels of manuring in 1942-43, were due to excessive showers of rain.

Yields of green fodder showed great variation under the influence of farmyard manure and irrigation in the year 1943-44. They were 770 maunds per acre with no manuring and high irrigation level, and increased to 861 maunds and 912 maunds as the dose of farmyard manure was increased. The produce showed considerable decline as the frequency of irrigation and the dose of manure were decreased. It was, therefore, concluded that high level of manure with high level of irrigation was highly beneficial for increasing the yields of sudan grass. These results agreed with those of Rackman [1941], who found that application of large amounts of water would increase yields to a significant degree only with heavy application of nitrogen.

Interaction of cutting treatment with different levels of irrigation and manuring

From the Table of analysis of variance, it was apparent that the interaction of three factors, viz., three cutting intervals, three levels of irrigation, and three intensities of manuring, was highly significant in the second experiment during 1943-44. Table VI below shows the yields as influenced by the interaction of these three factors :

TABLE VI

Interaction of interval of cutting with irrigation and manuring
(*Yield per acre in maunds*)

Year	Interval of cutting	Irrigation after			Manures			Mean	Increase	Significant of result
		1 week	2 weeks	3 weeks	No.	375 md.	750 md.			
1942-43	30 days	573	563	505	520	561	559	547	..	Yield±17·1
	40 days	660	633	610	628	651	624	634	+87	Mean±10·0
	50 days	663	607	610	582	638	660	627	+80	Increase±14·1
	Mean	632	601	575	577	617	614	—	—	
	Increase	+31	—	—26	—	+40	+37	—	—	
1943-44	30 days	762	709	634	613	687	805	702	—	Yield±25·4
	40 days	893	785	670	732	781	835	783	+81	Mean±14·8
	50 days	886	810	791	810	886	791	829	+127	Increase±20·8
	Mean	847	768	698	697	774	843	—	—	
	Increase	+79	—	—70	—	+70	+146	—	—	

From the Table VI given above, it was concluded that the two intervals of cutting of 40 and 50 days' were significantly superior to the cutting interval of 30 days', but there was no significant difference among them in 1942-43. These results were confirmed in the second experiment during 1943-44, with the difference that yields under 50 days' interval were higher than under 40 days' interval. The table further shows that higher yields were obtained by the application of farmyard manure. The differences between high and low levels were significant in the second experiment only. Similarly highest yield was obtained with maximum number of irrigations, and it was reduced as the frequency of irrigation was reduced. Further it was apparent that yield of green fodder was directly proportional to the various treatments, and that 40 days' interval, with high level of irrigation and high level of manuring, gave the best results.

Effect of various treatments of cutting, irrigation and manuring on the quality of the grass

The quality of any grass is usually determined by carrying out either digestibility trials or through its various constituents. Though conclusive evidence, regarding the relative feeding value and digestibility of a feed, can only be secured through the former, its value to a great extent is indicated by its chemical analysis, as the dry matter is made up of crude protein, fats, etc., and other constituents as lime, phosphate and potash, etc. The latter method was, therefore, adopted.

Chemical analysis of the same plant species may vary greatly, depending upon the soil in which the plant grew, the stage when cut, the amount of irrigation water applied, and the presence of diseases, etc. Indeed any factor which affects the growth of the plant also affects its composition. Piper [1937] reported the results of extensive experiments on the effect of fertilizers on the protein content of grasses, conducted at the Connecticut Experiment Station. In every case protein content of the grass was higher when nitrogenous fertilizers were applied. In general the protein content of grasses increased with the amount of nitrogen applied as fertilizers. But results of similar experiments with Timothy and Italian Rye grass did not indicate any definite effect on the protein

composition in one year, and increased the protein content in the second year. The variation in the chemical composition depending upon the stage of development, has also been studied in various crop plants by many investigators. Chemical composition of Timothy as affected by the time of harvesting, indicated great variations in the various constituents as water, ash, protein, fibre, nitrogen free extract and fat, in plants harvested at varying stages of growth.

According to Lander [1937] recent research has shown the supreme importance of individual constituents. But our knowledge with regard to Indian fodders, and especially those recently introduced, is very limited.

With a view to achieve this objective, oven dried samples were supplied to the Agricultural Chemist, Lyallpur. The results relating to each of the constituents as influenced by different treatments are given in Table VII.

TABLE VII

The percentage of dry matter of sudan grass under various treatments

(i) *Percentage of dry-matter in 1942-43*

Cutting intervals	Manure *nil*			Manure 375 md.			Manure 750 md.			Mean
	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks	
30 days . .	20·3	19·3	20·1	19·1	19·6	19·6	19·2	20·9	20·1	
40 days . .	21·1	21·2	23·7	20·7	22·7	23·8	21·1	21·0	23·0	
50 days . .	24·0	25·0	24·0	23·1	25·0	24·1	23·2	24·0	25·2	

(ii) *Main effects and interaction of intervals with manures and irrigation*

Cutting interval	Irrigation			Manure			Mean	Increase	Significance
	1 week	2 weeks	3 weeks	0	375 md.	750 md.			
30 days . . .	19·6	19·9	19·9	20·0	19·4	20·1	19·8	—	Dry matter ±·045
40 days . . .	21·0	21·6	23·5	22·0	22·4	21·7	22·0	+2·2	Mean ±·26
50 days . . .	23·2	24·9	24·9	24·8	24·1	24·1	24·3	+4·5	Increase ±0·36

(iii) *Interaction of manure with irrigation*

Irrigation	Manure			
	nil	375 md.	750 md.	
1 week	21·6	20·9	21·1	
2 weeks . . .	22·0	22·4	22·0	Manure ±·45
3 weeks	23·1	22·5	32·8	

The percentage of dry matter increased significantly with the increase in the interval between two cuttings from 30 to 40 days and from 40 to 50 days. It was reduced with high frequency of irrigation by ·8 and increased by ·7 under scanty irrigation.

The effect of farmyard manure was not marked. The dry matter decreased by ·3 with both low and high levels of manuring, but differences between them were insignificant.

Proteins

The percentage of proteins decreased as the interval between two cuttings was increased. It was 7·9 per cent. in the young stage, when cutting was taken at an interval of 30 days, but decreased significantly in the other two cutting variables of 40 and 50 days' to 7·0 per cent. and 5·0 per cent. respectively.

The higher the frequency of irrigation, the lower was the percentage of protein. It was the highest 7·1 per cent. when irrigation was applied after three weeks, and decreased to 6·9 per cent. and 6·7 per cent. with increase in the frequency of irrigation to two weeks and one week respectively.

The application of the different doses of farmyard manure did not show any marked effect on the variation of proteins. It was most probably due to the frequent showers of rain, which were received during the growing period of the crop. As a matter of fact higher soil moisture with heavy application of manure should have increased the percentage of protein, Rackman [1941], but results in this case did not show any marked effect of manure on increasing the percentage of nitrogen.

Table VIII showing the variation of protein under different treatments is given below :

TABLE VIII

The percentage of proteins as influenced by various treatments in 1942-43

Cutting interval	*nil*			Manure 375 md.			750 md.		
Irrigation	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks
30 days	7·5	3·0	7·8	8·6	8·4	7·8	8·2	7·1	8·1
40 days	6·9	7·3	7·1	6·7	6·4	7·2	6·5	7·5	7·0
50 days	5·0	5·7	6·5	5·6	5·5	6·1	5·7	6·4	5·6

TABLE IX

Main effects and interaction of interval of cutting with manures and irrigation

Cutting interval	Irrigation			Manure			Mean	Increase	Significance
	1 week	2 weeks	3 weeks	*nil*	375 md.	750 md.			
30 days	8·1	7·8	7·8	7·7	8·2	7·8	7·9	—	Protein ±·018
40 days	6·7	7·1	7·1	7·1	6·8	7·0	7·0	—0·9	Mean ±·11
50 days	5·4	5·8	6·0	5·7	5·7	5·8	5·0	—2·2	Increase ±·15
Mean	6·7	6·9	7·1	6·8	6·8	6·9	6·9	—	
Increase	—0·2	—	+0·2	—	—	—	—	—	

Interaction of manures and irrigation

Irrigation	Manures		
	nil	375 md.	750 md.
One week	6·5	7·1	6·8
Two weeks	7·0	6·8	7·0
Three weeks	7·1	7·0	7·2

Lime

Table X below shows the percentage of lime and its variation under the influence of different treatments of cuttings, irrigations and manures.

The percentage of lime showed a definite decline with the increase in the cutting interval. It was ·77 per cent. in 30 days' cutting interval, and ·72 per cent. and ·66 per cent. with the other two cutting treatments of 40 and 50 days' respectively.

The high level of irrigation favoured the increase of lime, but there was no significant difference in the other two levels of two weeks and three weeks.

The application of manure did not affect the percentage of lime. It was the highest in no-manure treatment.

TABLE X

The percentage of lime as influenced by various treatments in 1942

Cutting interval	Manure-*nil*			375 md.			750 md.		
Irrigation	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks
30 days	·81	·73	·75	·78	·75	·77	·84	·74	·75
40 days	·76	·76	·72	·73	·69	·69	·72	·71	·70
50 days	·71	·70	·66	·65	·64	·65	·66	·65	·65

Main effects and interaction of interval between cuttings with manure and irrigation

Cutting interval	Irrigation			Manure			Mean	Increase	Significance
	1 week	2 weeks	3 weeks	*nil*	375 md.	750 md.			
30 days	·81	·76	·74	·76	·77	·78	·77	—	
40 days	·73	·70	·72	·74	·70	·71	·72	—·05	Calcium ±·017
50 days	·67	·66	·66	·69	·64	·65	·66	—·11	Mean ±·010
Mean	·74	·71	·71	·73	·70	·71	·71	—	Increase ±·014
Increase	+·03	—	—	—	—	—	—	—	

Interaction of manures with irrigation

Irrigation	*nil*	375 md.	750 md.
1 week	·76	·72	·70
2 weeks	·73	·69	·71
3 weeks	·71	·74	·70

Phosphates

As far as phosphates were concerned, it was concluded that under different treatments of cutting intervals, and different intensities of manuring and irrigation, the percentage of phosphates was the highest in the young stage of 30 days' cutting intervals, and showed direct influence of the increase in cutting interval, as it decreased to ·53 per cent. and ·46 per cent. with 40 and 50 days' cutting intervals respectively.

As regards the effect of irrigation on the percentage of phosphates, it was observed that it decreased with scanty irrigation given after every three weeks interval. The application of manure, however, increased the percentage from ·50 per cent. to ·53 per cent. in the low and high manuring treatment respectively.

TABLE XI

The percentage of phosphates as influenced by different treatments

Cutting interval	No manure			375 md.			750 md.		
	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks
30 days	·54	·54	·53	·61	·60	·58	·62	·62	·60
40 days	·53	·53	·45	·59	·51	·51	·56	·56	·55
50 days	·46	·43	·45	·44	·48	·47	·48	·46	·48

Main effects and interaction of interval between cuttings with manures and irrigation

Cutting interval	Irrigation			Manure			Mean	Increase	Significance
	1 week	2 weeks	3 weeks	*nil*	375 md.	750 md.			
30 days	·58	·59	·57	·54	·59	·61	·58	—	
40 days	·56	·53	·50	·51	·54	·55	·53	—·05	P_2O_5 ±·012
50 days	·46	·46	·46	·44	·46	·47	·46	—·12	Mean ±·007
Mean	·53	·53	·50	·50	·53	·54	—	—	Increase ±·010
Increase	—	—	—·02	—	+·03	+·04	—	—	

Interaction of manures and irrigation

Irrigation	Manures		
	nil	375 md.	750 md.
1 week	·51	·54	·55
2 weeks	·50	·53	·55
3 weeks	·47	·52	·54

Potash

The cutting intervals also influenced the percentage of potash and showed the same results as phosphates. There was a gradual decrease as the interval between cuttings was increased. It was 3·2 per cent. in 30 days' cutting interval and 3·12 per cent. and 2·83 per cent. in 40 and 50 days' intervals respectively.

The high level of manuring and irrigation increased the percentage to a slight extent. but the increase noticed was not significant, as is shown in Table XII below :

TABLE XII

The percentage of potash as influenced by various treatments

Cutting interval	No manure			375 md.			750 md.		
	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks
30 days	3·12	3·20	3·15	3·16	3·19	3·16	3·29	3·31	3·20
40 days	3·16	3·22	3·05	3·16	3·00	3·03	3·12	3·23	3·07
50 days	2·88	2·75	2·76	2·92	2·75	2·78	2·96	2·88	2·83

Main effects and interaction of interval between cuttings with manure and irrigation

Cutting interval	Irrigation			Manure			Mean	Increase	Significance	
	1 week	2 weeks	3 weeks	*nil*	375 md.	750 md.				
30 days	3·19	3·23	3·17	3·16	3·17	3·26	3·20	—		
40 days	3·15	3·15	3·05	3·14	3·07	3·14	3·12	—·08	K_2O	±·045
50 days	2·92	2·79	2·79	2·79	2·81	2·89	2·83	—·37	Mean	±·026
Mean	3·09	3·06	3·00	—	—	—	—	—	Increase	±·036
Increase	+·03	—	—·06	—	—	—	—	—		

In addition to the studies mentioned above, considerable breeding work has been under way at the Fodder Research Station, Sirsa, with a view to improve the original sudan grass and to isolate some superior strains. But no strains of exceptional value however, have been developed and the

grass as introduced at first is a satisfactory forage plant. The work is in progress to find out high yielding strains as well as to breed sweet strains of the grass. A dozen of them were studied in detail and showed fairly high sugar content, but they did not maintain their ability to yield high quantities of green stuff, because of their very slow growth.

Summary

Results of the study of sudan grass under different systems of management at the Fodder Research Station, Sirsa, are presented. The aim of the present investigation was to determine (*a*) the effect of varying intervals of cutting on yield, (*b*) the response of the grass to different intensities of manuring and irrigation, and (*c*) the effect of these treatments on the quality of the grass.

The yield data and those of chemical constituents were analyzed according to Fisher's analysis of variance.

The results showed that the best stage of harvesting sudan grass was when most of the panicles were out of the sheath, and that the most suitable cutting interval, considering all aspects, was 40 days.

Differences in yields resulting from the three cutting variables, 30, 40 and 50 days, were highly significant in both experiments. Yields in 40 and 50 days' intervals were significantly higher than those obtained under 30 days' interval, but differences in 40 and 50 days' were not significant.

The influence of different levels of irrigations and manuring was definitely in favour of the highest level, 750 maunds manure and irrigation after every week respectively. The interactions were non-significant in the first experiment and were highly significant in the second. As a result of the study of interaction of various treatments, it was concluded that 40 days' interval between two cuttings with highest frequency of irrigation and manuring, gave the best performance.

The chemical composition of the grass was influenced by the various treatments.

The dry-matter increased with the increase in the cutting interval, but was reduced with irrigation and manuring.

The percentage of protein varied inversely with the cutting interval and frequency of irrigation, but did not show appreciable response to manuring.

The percentage of lime, phosphates and potash showed significant decrease with the increase in cutting intervals. While high level of irrigation increased the percentage of all these constituents, the effect of different doses of farmyard manure was not marked.

Breeding with a view to evolve high yielding strains has met with little success so far.

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NON			EXP			
T3	M3	I_1	T3	M2	I_3	1
T2	M1	I_1	T2	M2	I_3	2
T1	M1	I_2	T2	M1	I_1	3
T3	M2	I_2	T3	M3	I_1	4
T3	M1	I_3	T2	M2	I_3	5
T2	M3	I_2	T1	M2	I_1	6
T1	M2	I_2	T3	M1	I_2	7
T2	M2	I_3	T1	M3	I_2	8
T1	M3	I_3	T1	M1	I_3	9
T1	M1	I_3	T1	M2	I_2	10
T2	M3	I_3	T1	M1	I_1	11
T1	M3	I_1	T3	M1	I_3	12
T2	M2	I_1	T2	M1	I_2	13
T1	M2	I_2	T2	M2	I_3	14
T3	M2	I_3	T3	M3	I_2	15
T3	M3	I_2	T3	M2	I_1	16
T3	M1	I_1	T2	M3	I_1	17
T2	M1	I_2	T1	M3	I_3	18
T2	M3	I_1	T1	M2	I_3	19
T3	M3	I_3	T3	M2	I_2	20
T1	M1	I_1	T2	M1	I_3	21
T2	M1	I_3	T2	M3	I_2	22
T1	M3	I_2	T3	M1	I_1	23
T2	M2	I_3	T1	M1	I_2	24
T1	M2	I_3	T2	M2	I_1	25
T3	M2	I_1	T3	M3	I_3	26
T3	M1	I_2	T1	M3	I_1	27
NON			EXP			

Manure
Reference—
M1—No manure
M2—Medium manure
M3—High manure

Cutting interval
Reference—
T1—30 days
T2—40 days
T3—50 days

Irrigation
I_1—after two weeks
I_2—after one week
I_3—after three weeks

Size of plot—1/50th acre in 1942 and 1/40th in 1943

FIG. 1.—Plan of sudan grass complex experiment, 1942-43 and 1943-44.

STUDIES ON HOST RESISTANCE OF COTTON TO STEM WEEVIL (*PEMPHERULUS AFFINIS*)

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In parts of Madras Province where Cambodia cotton (*G. hirsutum II and G*) is being grown extensively, plants are found to wither and die all of a sudden. In some years, the mortality of plants exceeds 25 per cent. This has been traced to the damage caused by an insect known as cotton stem weevil (*Pempherulus affinis*). Ramakrishna Ayyar [1918] and Ballard [1922] studied the life history of this weevil in detail and found that the insect passed its whole life cycle from egg to adult stage inside the cotton stem. As such, normal methods of insect control, like spraying or dusting contact and stomach poisons were not efficacious, in exterminating or controlling the insect. They suggested the adoption of a fairly protracted 'no cotton period' between two successive cotton crops, as the only effective measure for controlling the multiplication of the insect and for reducing plant mortality in cotton. The cotton Pest Act passed by the Madras Government in [1919] required the compulsory removal of the Cambodia cotton crop, before a certain date. In practice, the actual enforcement of this provision was, however, found difficult, since a large section of farmers stood to gain by the retention of the crop till late August, for gathering a second harvest. These farmers generally succeeded in getting the necessary relaxation in the original date fixed for uprooting cotton stalks and indirectly defeated the purpose of the Act, *i.e.*, the creation of an effective 'no cotton period' between the harvest of one crop and the planting of the next crop. Hence studies on host resistance of cotton to stem weevil were taken up as an item of work in the botanical wing of the Madras Pempheres Scheme, with the object of breeding types, capable of resisting the attack of the insect. Concurrently, a search for other remedial measures, through changes in agronomy, was also made. The investigations, the results of which are compiled in this paper, were carried out at the Cotton Breeding Station, Coimbatore, between the years [1931 to 1943].

Previous work

Snelling [1941] reviewed the present knowledge on the resistance of plants to insect attack under 15 different plant characteristics known to exert some influence on host resistance. None of these factors, however, were studied previously with reference to cotton stem weevil, till the publication of the results on the mode of infestation, gall development, gum formation, defensive mechanisms, agronomic palliatives and biological control by Dharmarajulu and others [1934], Dharmarajulu [1935] and Krishna Ayyar [1938]. The last named author observed (*a*) considerable variations in fecundity and development of the insect when bred on different parts of the cotton plant, (*b*) the higher incidence of the weevil in the irrigated winter sown Cambodia crop, as, due to the existence of a favourable range of temperature at Coimbatore and (*c*) the absence of the insect in Tinnevelly district and H.E.H. the Nizam's Dominions, to be related, to the prevalence of high temperature during the phase of crop growth and the long off-seasonal period following it. According to Dharmarajulu [1935], the insect punctured the epidermis and laid an egg in a cavity at the cortical region in young seedlings and in the wedge-shaped medullary ray in older plants : on hatching, the grub extended the cavity and tunnelled round the stem feeding on the meristematic tissue of the cambium ; even prior to the cutting out of a pupal chamber, it prepared an easy exit for emergence and as a result of the injury caused to the tissues during tunnelling, plants were found to wither and die. In some varieties, tissue regeneration, indicated by gall like swellings, was noticed on the primary stem at the hypocotyl region. The shape, size and number of galls depended on the proliferation

of the callus, the activity of the injured cambium and the number of infestations. The stem which was usually weak at such points, had a tendency to break in periods of windy weather. The attack in certain other varieties which did not develop galls or die, could be detected by the presence of healed up exit holes on the stem. Examination of the insect burrows revealed the presence of a gummy substance different from similar exudates obtained in plants like *acacia* and *moringa*. The exudate, in this case, consisted of a sticky matrix which flooded the insect gallery, prevented the movement of the grubs and ultimately disintegrated them. The capacity to kill the grub by gum production or to repair the damage by gall formation, was therefore taken and used as definite evidence of host resistance or host tolerance respectively.

Methods

The experiments and observations, detailed herein, were conducted on the winter Cambodia cotton (September to March), at the Cotton Breeding Station, Coimbatore. From the year [1936] the pace of breeding work was speeded up by raising another summer crop (March to September), at Srivilliputhur in Ramnad district. There were thus two crops per year, where, there was only one before. At Coimbatore, two waves of insect incidence, corresponding to the months of November and February, were regular features. Single infestations were very common in the November wave, but yet the two month old seedlings were usually unable to resist and succumbed to the weevil attack in large numbers. The incidence of the weevil attack was also found to vary within a field and to be influenced by the season and the environment in a particular locality. In general, the winter crop at Coimbatore was subject to a higher mortality than the summer crop at Srivilliputhur, while the number of plants allowing adult emergences, were greater in the summer crop at Srivilliputhur, as Table I would indicate.

Table I

Year	Coimbatore		Srivilliputhur		
	No. of plants taken for examination	Percentage of mortality	Percentage of adult emergence	No. of plants taken for examination	Percentage of mortality	Percentage of adult emergence
1936 . . .	7914	13·2	39·0	—	—	—
1937 . . .	10459	26·1	28·7	2299	2·4	47·5
1938 . . .	8419	23·0	19·1	2490	7·2	74·0
1939 . . .	10407	57·5	30·5	1927	4·0	47·0
1940 . . .	8255	24·0	46·0	1667	2·5	47·9

Percentage mortality=Number of plants dying out of every 100 plants attacked by the weevil.
Percentage adult emergence= Number of plants allowing the insect to breed and emerge as adults out of every 100 plants attacked

It would appear, that the lower temperature and higher humidity prevailing at Coimbatore were more conducive for the quicker development of the burrowing larvae than of the host plant, while the higher temperature and lower humidity at Srivilliputhur seemed to be equally congenial

for the rapid growth of both the cotton plant and tunnelling grubs. In consequence, adult emergence was higher and plant mortality lower in the summer cotton crop. Krishna Ayyar [1938] concluded from a study of temperature and humidity requirements of the insect in its various stages of development, that a range of 60 per cent. to 80 per cent. humidity was favourable for the early larval stages while the requirements of the advanced stages were the reverse, and that temperatures above 42°C. were lethal.

The above mentioned differences, noticed in the reaction of host to the attacking weevil, required a change in the criteria, adopted for assessing comparative resistance in the two centres of trial. Low mortality at Coimbatore and low adult emergence at Srivilliputhur were therefore taken as indices for selection of resistant types. A very high initial infestation is essential at the age of maximum susceptibility, in order, to spot out the resistant from the susceptible variety. This was sought to be realized by spreading evenly and periodically infested stems of Cambodia, indigenous cotton and the alternate host plant *Triumphetta rhomboidea* containing the advanced stages of the pest by the side of every row of cotton seedlings when they were two months old. This did not prove to be an unqualified success, because (*a*) difficulties were experienced in securing the requisite number of infested Cambodia stems, (*b*) the adult emergences from the rapidly drying Asiatic cotton stems were low, (*c*) the adults emerging out of *Triumphetta rhomboidea* did not infest cotton readily. Wide variations in the incidence of weevil attack within the same field were therefore inevitable and the mere presence of insect population was not a sufficient guarantee for uniform or high infestation, if the environment was not equally congenial for oviposition. Hence an extensive system of controls was provided by sowing the susceptible variety —Cambodia strain Co2—every fifth row to serve as checks. The resistance of various cultures, judged by their percentages of mortality and adult emergence, should be taken as relative but not absolute.

It would be apparent from the above, that the total absence of both plant mortality and adult emergence under such controlled experiments would constitute the breeder's ideal of resistance. In actual practice, however, it was never obtained. Control strain Co2 had given an average of 20 per cent. mortality and 40 per cent. adult emergence over a series of years. Hence low mortality, combined with adult emergence not exceeding five per cent., was fixed as the basis for selection at Coimbatore, in addition to the standards defined for staple-length, ginning outturn and yield.

Experimental results

(*a*) *Breeding experiments*

(i) *Pure line selection*

Every field of Co2 crop invariably contained a mixed population of dead, attacked and free plants. Four hundred and sixty nine plants falling under the last category were selected and their progenies were studied for three years under conditions of heavy artificial infestation. There was no difference in resistance between the selected progenies and unselected bulk nor was there any gradual fall in the mean mortality values of the cultures subjected to repeated reselection. The absence of any outstanding difference in the degree of susceptibility between the two groups over a series of years, would connote that the regular occurrence of free plants should be viewed as escapes, and that the pursuit of such plants was unlikely to lead to the isolation of a resistant biotype in Co2. Consequently further work on selection in Co2 was given up.

(ii) *Varietal resistance*

In addition to selection work on pure lines, detailed notes were recorded on a large number of indigenous and exotic varieties, grown in few rows at Coimbatore, both as irrigated and unirrigated crops. None of the varieties were immune to stem weevil attack. The unirrigated crop on the black soil, usually managed to escape the first wave of infestation and recorded low mortality values. From the year [1933-34] a few select varieties from each botanical group, were raised as irrigated crop and subjected to regular test for resistance under artificially infested conditions, both in replicated and non-replicated plots. The data secured from these trials are presented in Table II.

TABLE II

Name of variety	(1933-34)		(1934-35)		(1935-36)		(1935-36)
	Population	Percentage mortality	Population	Percentage mortality	Population	Percentage mortality	Percentage adult emergence
Gossypium barbadense—							
Peruvian	47	0	41	0*	—	—	—
Quebradinho	—	—	1,932	2*	347	1	1
Verdao	—	—	2,150	0*	347	3	—
Gossypium purpurescens—							
Moco	—	—	1,923	0*	302	2	1
Bourbon	69	3	29	2	377	2	3
Herbaco	—	—	48	19	363	11	8
Gossypium hirsutum—							
U.4/4	41	40*	30	48	342	17	17
Russian	271	23	35	0*	366	11	17
1867	29	41*	37	11*	329	16	15
Buri	—	—	99	30	351	11	14
Gadag	492	25	46	26	358	10	14
Co2	687	57	61	49	5,052	17	16
Gossypium arboreum—							
K 546	—	—	—	—	143	40	30
N 14	—	—	—	—	216	20	49
Cocanadas	—	—	—	—	178	32	56
Roseum	—	—	—	—	192	33	66
Nadam	—	—	78	0	298	6	56
Gossypium herbaceum—							
H.1	—	—	—	—	175	39	64
Uppam	—	—	—	—	312	15	86

* Unreplicated

The varieties, recording consistently low percentages were *Peruvian*, *Quebradinho* and *Verdao* under *Gossypium barbadense*, *Moco* and *Bourbon* in *G. purpurescens* and *Nadam* in *G. arboreum* group. Detailed observation on the resistant group disclosed, that the three South-American varieties *Quebradinho*, *Verdao* and *Moco* arrested the development of the grub by the production of a gummy exudation, while *Bourbon* and *Nadam* types withstood the attack through their capacity for rapid regeneration of damages tissued by the production of galls on the stem. It was also apparent, that all indigenous varieties except *Nadam* were more susceptible when raised as an irrigated crop and

that their lower mortality as unirrigated crop was, partly, due to their late planting and, partly, to the factors of temperature and humidity in rain-fed areas. The low percentage of mortality, recorded by Nadam, is in keeping with its performance in its native habitat where it is grown, mixed with Bourbon, under conditions of heavy infestation of the stem weevil.

An experiment was designed to find whether the resistance manifested by three South-American varieties was due to any repellance possessed by them. They were grown, along with four other relatively susceptible types and artificially infested. The results in Table III do not show any large differences in the total number of infestations and as such, it must be concluded, that the resistance was not due to any repellance.

TABLE III

Variety	Mean percentages of			Total number of infestations
	Mortality	Gumming*	Adult* emergence	
Quebradinho	0·5	95·5	2·1	161
Verdao	3·0	96·5	0·5	177
Moco	1·2	99·0	0·6	350
Russian hirsutum	20·0	79·0	12·0	205
(A12×Co2)× 4383	59·0	32·0	63·0	190
(Co2×U.4/4)× 3915	33·0	87·0	8·0	210
Co2	32·0	66·0	21·0	212

* Expressed as percentages on total number of infestations

The innate virtue of the resistant South-American group of varieties appeared to lie in their capacity for rapid plant growth and for retardation in the development of the insect during the larval stage by gumming. Unfortunately, however, all the resistant varieties from the *barbadense* and *purpurescens* groups were very late in maturation, defective in boll dehiscence, susceptible to jassids, and low in productivity. They were, therefore, considered to be, at best only desirable parents for the artificial synthesis of resistant biotypes.

(iii) *Hybridization*

The locally established strain Co2, belonging to *G. hirsutum*, was used as a parent for crossing in the beginning but the latest strains and substrains were later on employed when they became available. Since the parents belonged to different species, the technique of back-crossing recommended in such wide interspecific hybridization, was largely employed and often repeated upto the fourth back-cross stage, before applying selection. The economic side of the problem was kept as the main objective, subordinating the genetical aspects of host resistance. Consequently, the data collected and presented under this head should be considered as incomplete.

The results, on the aspects of mortality and adult emergence in the several generations of the different hybrids, are presented in Table IV. The resistance of the first generation hybrids was in general higher than either the second generation or the first back-cross to the susceptible parent. The mortality, as well as, adult emergence increased when the susceptible type was back-crossed more than once *vide* Table V.

TABLE IV

Nature of cross	First generation		Second generation	
	Mortality percentage	Adult emergence percentage	Mortality percentage	Adult emergence percentage
QC	0	—	31	4
CQ	11	—	18	18
QC^2	21	57	29	22
C^2Q	20	13	33	25
QC^3	—	—	29	29
C^3Q	24	35	35	20
QC^4	26	43	—	—
C^4Q	—	—	—	—
VC	8	—	37	19
CV	12	—	19	27
VC^2	21	—	—	—
C^2V	0	25	26	35
VC^3	21	53	35	25
C^3V	16	30	36	24
VC^4	23	31	—	—
C^4V	19	35	—	—
MC	2	2	9	17
CM	7	2	8	25
MC^2	5	35	16	11
C^2M	5	42	15	21
MC^3	23	26	29	—
C^3M	32	32	—	—
MC^4	12	7	29	—
C^4M	10	7	—	—

TABLE V

Nature of cross	Range of percentage mortality	Mean per cent mortality	Range of percentage adult emergence	Mean per cent adult emergence
$M \times C^2$	0 to 45	8·9	0 to 25	6·0
$M \times C^3$	0 to 45	15·0	0 to 45	13·7
$M \times C^4$	0 to 35	19·7	0 to 50	19·2

Q=Quebradinho V=Verdao M=Moco C=Cambodia Co2 —=No data

Superscript denotes the number of doses. This notation has been followed throughout.

Another interesting observation was, that the mortality in the first generation hybrids occurred mostly during the first wave of infestation in the month of November when the seedlings were young, while they resisted the second wave in February to a very high degree. These preliminary trials suggested that resistance to stem weevil was probably a partially dominant heritable character.

The hybrid vigour of these interspecific crosses closely followed the trends of insect resistance. The vigour in the first generation was gradually reduced by a repeated back-crossing to Co2, and the four times back-crossed population could not be distinguished from the susceptible parent stock itself, in morphological features or growth. The differences, if any, lay in the fibre characters only.

In addition to crosses mentioned in Table IV, others with *Bourbon* and three-way crosses involving *G. hirsutum G. barbadense* and *G. purpurescens* were also effected and studied. The work on the latter combination was considered necessary, since direct or back-crosses between species proved to be generally disappointing. About 5,527 cultures derived from the above hybrids were studied in detail under properly laid out trials. It was noticed that (*a*) derivatives of *Barbadense* hybrids were more resistant, than others, to stem weevil but poor in productivity and (*b*) the *Purpurescens* group of parents especially *Moco*, imparted resistance, in combination with other economic characters. Details of the work done on the selection of biotypes combining resistance and other characters, are summarized under the heads *Moco* hybrids, *Bourbon* hybrids and *Interstrain* hybrids.

Moco hybrids

Selection in second generation and back-cross populations beyond the first back-cross stage failed to yield resistant biotypes superior to the local in productivity and quality. Only two derivatives, viz. 7176 and 7178 of first back-cross continued to record consistently very low mortality and adult emergence during the entire period of test. Table VI gives the relevant information for these two types, along with the performance of their respective control. Of the two cultures, 7176 was dull coloured and short-stapled while 7178 was of good quality but not productive. Both of them were defective in other respects as they possessed trailing habit, late maturity, small boll size, bad boll dehiscence, and bud shedding. A sustained attempt to eliminate the defects by reselection was of no avail.

Bourbon hybrids

The earlier studies had shown, that the resistance of *Bourbon* variety was due to its capacity for rapid regeneration of the attacked region by gall formation. Two derivatives, viz. 4151 and 4413 from the third back cross proved to be the best of the whole lot. The initial high adult emergence, noticed in the third generation, was considerably lowered by repeated reselection in the subsequent generations. The performance of the best families in 4413 and 4151 are given in Table VII. The superiority of 4413, in regard to both yield and resistance was, however, not maintained and the culture became very susceptible to blackarm. Reselections failed to yield any outstanding biotype, superior to Co2.

Interstrain hybrids

The defects in the best four derivatives from *Moco* and *Bourbon* crosses could not be eliminated, in spite of reselection. Hence further crossing with *Hirsutum* selections was taken up and pursued.

TABLE VI

Place and year of trial	Percentage yield on control			Percentage mortality			Percentage adult emergence			Maximum halo length in mm.			Ginning percentage		
	7176	7178	Co2	7176	7178	Co2	7176	7178	Co2	7176	7178	Co2	7176	7178	Co2
Coimbatore—															
(1938) . . .	114	100	100	3	4	17	3	1	15	24	25	25	35	33	34
(1939) . . .	121	88	100	29	45	67	10	7	24	24	25	25	32	30	33
(1940) . . .	112	116	100	9	9	23	Not examined	10	43	26	25	25	30	33	34
(1941) . . .	Not sown	86	100	Not sown	13	27	Not sown	16	45	Not sown	25	26	Not sown	32	33
Srivilliputhur—															
(1939) . . .	90	75	100	Not recorded due to poor infestation						27	27	25	32	34	35
(1940) . . .	112	70	100	0	0	2	15	19	82	26	26	27	30	31	26

TABLE VII

Place of trial and year	Percentage yield on control				Percentage mortality				Percentage adult emergence				Maximum halo length in mm.				Ginning percentage			
	4413,1	4413,2	4413,3	4151,2	4413,1	4413,2	4413,3	4151,2	4413,1	4413,2	4413,3	4151,2	4413,1	4413,2	4413,3	4151,2	4413,1	4413,2	4413,3	4151,2
Coimbatore—																				
(1938) . .	210	174	139	186	25	4	13	10	4	2	2	10	25	26	26	25	32	34	36	36
Srivilliputhur—																				
(1938) . .	112	114	137	109	7	4	4	5	58	38	50	61	26	25	25	26	33	31	32	34
Coimbatore—																				
(1939) . .	100	104	112	127	10	7	11	12	7	4	5	10	28	27	28	28	33	33	31	32

TABLE VIII

Nature of species used for crossing	Parentage	No. of cultures tested in progeny rows in different generations												Cultures tested in small bulk tests during (1939 to 1943)						
		F2	F3	F4		F5		F6		F7		F8		F3	F4	F5	F6	F7	F8	
				Cultures	Sibs	Cultures	Sibs	Cultures	Sibs	Cultures	Sibs	Cultures	Sibs							Total
M[2] .	7176×4463	76	44	7	29	2	10	2	10	—	—	—	—	1	2	1	—	—	—	4
	7176×4456	44	16	4	16	3	12	1	2	—	—	—	—	1	—	—	—	—	—	1
	7178×4463	244	184	36	140	25	217	15	170	5	100	1	44	7	10	13	12	16	—	58
	7178×4456	294	198	43	137	34	234	9	178	2	71	—	—	6	14	8	6	—	—	34
B×C[4] .	4413×4463	66	21	10	24	3	46	1	4	—	—	—	—	2	3	—	—	—	—	5
	4151×4463	30	21	8	21	4	28	2	2	—	—	—	—	—	—	—	—	—	—	—
	4151×4456	27	27	6	19	3	22	3	33	—	—	—	—	3	1	3	—	—	—	7
	4151×7178	33	9	6	11	4	16	1	3	—	—	—	—	—	2	—	—	—	—	2

TABLE IX

Economic characters of resistant cultures during the years 1940-41 to 1943-44 at Coimbatore

Strain No.	Percentage yield on control				Percentage mortality				Percentage adult emergence				Maximum halo length in mm.				Ginning percentage			
	(1940-41)	(1941-42)	(1942-43)	(1943-44)	(1940-41)	(1941-42)	(1942-43)	(1943-44)	(1940-41)	(1941-42)	(1942-43)	(1943-44)	(1940-41)	(1941-42)	(1942-43)	(1943-44)	(1940-41)	(1941-42)	(1942-43)	(1943-44)
1-37-1-2 . .	149	242	276	159	5	1	4	12	23	5	4	—	27	26	24	25	33	32	32	34
X-82-1-5 . .	154	132	233	170	16	5	0	10	6	20	19	—	28	28	24	26	32	34	34	35
X-102-2-4 . .	86	183	96	×	6	3	2	×	3	5	2	×	26	27	—	×	32	37	—	35
X-108 4-1 . .	132	177	191	214	4	10	3	11	5	28	10	—	25	26	22	24	32	36	35	34
Co2 (standard) .	100	100	100	100	24	19	29	29	46	39	54	—	-	26	23	24	-	33	-	34
Mean values for Co2 from other trials													25	25	24	24	34	34	35	35

N.B. × = Not tested —= No reading

Three of the best *Hirsutum* strains, viz. 920, 4456 and 4463 were chosen as parents, back-crossed once. The results furnished in Table VIII and Table IX indicated, that 7178 was the most resistant parent, while on the other side, 4456 and 4463 imparted vigour, quality, earliness and productivity. Four cultures, viz., I-37-1-2, X-82-1-5, X-102-2-4 and X-108-4-1 proved to be the best for combination of characters. None of these families suited the environments at Coimbatore and Srivilliputhur equally well. Selection number X-102-2-4 did well during summer at Srivilliputhur but failed at Coimbatore. The remaining three cultures recorded good yields as a winter crop at Coimbatore, but not as a summer crop at Srivilliputhur. Of these three selections, X-82-1-5 was consistent in plant mortality, yield and staple while the other two were defective in quality. All of them however, possessed trailing habit and coarse fibre. Re-selections in X-82-1-5 eliminated defects in habits but not in quality. It was apparent, that further improvement in fibre properties could be achieved, only, through further hybridization with quality strains.

The aim of the work described above, had been the synthesis of resistance, yield and quality by interspecific hybridization. Any attempt to breed for resistance by hybridization, is, by itself, a formidable task. The more so it is when resistance is found associated in varieties having poor economic characters. In this problem, we are further dealing with an insect having strong preferences for particular environments. Nevertheless, the work has demonstrated that the transference of resistance and economic characters can be done in discreet steps by slow synthesis.

(*b*) *Other studies*

Apart from controlling the pest by breeding for resistant strains, other methods were also tried. The known peculiarities of the insect suggested the trial of a few remedial measures. Its habit of laying eggs on the hypocotyl portion suggested the method of earthing up the basal region of plants. The light loving nature of the adults indicated that crowding in close spaced planting might prove beneficial. Further, the migration of the weevil from their hiding places to the newly sown cotton, suggested, the possibility of their being highly sensitive to smell and if it could be reduced by crop mixtures, the infestation could be minimized. These methods were therefore tested for their efficacy in the control of the pest.

(*i*) *Spacing and earthing*

Four variants, detailed in Table X, were tested against the control plot of cotton normally spaced without earthing. The monthly mortality were noted for all the plots. The results indicated that close spacing in combination with earthing up tended to keep down the mortality during the first wave, but not later. It would appear that earthing up of the basal portions of the seedlings checked the oviposition more effectively than cutting off light by crowding, but the former device was of no avail during the second wave, possibly, due to the oviposition on the exposed regions of the stem. The reduction, in the extent of damage shown by the total mortality figures, was not of such a magnitude, as to adopt it, as an efficient device.

TABLE X

Treatment	Percentage mortality during		Total mortality percentage
	First wave (Nov. to Dec.) (1933)	Second wave (Jan. to Mar.) (1934)	
(1) Normal spacing with no earthing	14·3	10·3	24·6
(2) Close spacing—4 in. plus earthing up	7·5	13·8	21·3
(3) Close spacing plus earthing up plus manure	8·3	13·4	21·7
(4) Close spacing plus manure plus fungus spray	12·7	11·1	23·8
(5) Close spacing plus manure plus water spray	15·2	13·7	28·9
Significance by 'Z' test	Satisfied	Not satisfied	Not satisfied
Conclusion	2, 3, 4, 1, 5		

N.B.—Normal spacing—$2\frac{1}{2} \times 9$ in. at two plants per hole (equates to 40,000 plants per acre approximately).
Manure—Basal dressing of farm yard manure at two tons per acre and top dressing of ammonium sulphate at one cwt. per acre applied at flowering time.
Fungus spray—Two sprayings with Richard's liquid media inoculated with II (white).

(ii) Crop mixtures

The aim in these trials was to test whether the plant odour connected with the cotton crop acted as a sufficient stimulus for the attraction of the stem weevil to the growing seedlings during the two waves of incidence and if so, whether the incidence could be reduced by mixed cropping. Three important millets of the Cambodia tract, viz., *Cumbu* (*Pennisetum typhoidem*), *Tenai* (*Setaria italica*) and *Ragi* (*Eleusine coracana*) were sown, mixed with cotton, along with minor variations in the time of planting and spacing. A highly susceptible pure strain Co.3 was used in both the trials. During the first experiment in [1941], six variants made up of two spacings, three kinds of mixtures, two planting dates and local method were tested. Neither were the percentages of plant mortality recorded in mixtures, *vide* Table XI, significantly lower than pure cotton nor were the growth and productivity of cotton in such mixtures as good as those of pure cotton. Since cotton in association with dibbled *Ragi* proved to be the best of the variants, the experiments in [1942] were elaborated, so as to retain, only the variants with *Ragi* in three different proportions in each of the transplanted and dibbled series. It would be evident from the mortality figures given in Table XI, that mixed cropping had failed to reduce the number of deaths in cotton. Evidently the insect does not appear to be particularly sensitive to other plant odours. The trial, nevertheless, indicated that *Ragi* would prove to be a suitable cereal for intercropping with cotton and that the practice was likely to prove more remunerative than pure cotton.

(iii) Internodal length

During the earlier studies on varieties, stunted plants were observed to be less susceptible than normal types. Among them three varieties in the American group, viz., *Ishan*, *Kidney* cotton and *Russian Hirsutum* and *Comilla-4-2* among the Asiatic cottons happened to be both stunted and tolerant to the pest. These were found to possess short internodes. It was thought, that reduction in hypocotyl region, as well as, internodal length possibly helped to keep down infestation. One hundred and eleven Cambodia plants from strain Co2 were selected at random and they were classified for insect attack as free, galled or gummed. The mean length of hypocotyl, first, second and third internodes, were determined in them and the data furnished in Table XII negative any relationship between internodal length and infestation.

TABLE XI

Crop mixture experiments

	(1941 to 42)	(1942 to 43)
Area of plot	0·233 per cent	0·70 per cent
Method of layout	Randomized blocks	Randomized blocks
Number of replications	Four	Six
Date of transplanting *Ragi*	(10-9-1941)	(11-9-1941)
Date of sowing cotton and other crops	(30-8-1941)	(11-9-1942)
Date of harvesting—		
(*a*) Period of harvesting cereals	(27-11-1941) to (6-12-1941)	(12-12-1942) to (2-1-1943)
(*b*) Period of harvesting cotton	February to March (1942)	February to March (1943)

Serial No.	Nature of mixture and spacing	Percentage mortality	Yield in lb. per acre			Percentage mortality	Yield in lb. per acre		
			Cotton kapas	Cereals			Cotton kapas	Cereals	
				Grain	Straw			Grain	Straw
1	Cotton only spaced 3 ft. × 9 in.	26	845	..	..	38	471	..	..
2	Cotton only spaced 3 ft. × 4 in.	20	793	..	..	34	470	..	..
3	Cotton *Cumbu* in alternate lines	36	206	..	6,280	..	..	..	..
4	Cotton *Tenai* in alternate lines	23	576	215	1,666	..	..	..	..
5	Cotton *Ragi* transplanted three weeks earlier than cotton (one row on opposite ridge)	24	418	2,043	2,018	..	..	..	..
6	Cotton *Ragi* transplanted on the same day as cotton (two rows between cotton rows)	..	..	..	..	33	453	2,180	3,051
7	Ditto (one row on the opposite ridge)	..	..	..	..	33	443	1,682	2,009
8	Ditto (two rows between alternate cotton rows)	..	..	..	..	35	451	1,382	1,420
9	*Ragi* dibbled on the same day as cotton (two rows between cotton rows)	..	..	..	..	33	402	2,127	3,713
10	Ditto (one row on the opposite ridge)	20	855	1,398	1,631	32	449	1,477	2,245
11	Ditto (two rows between alternate cotton rows)	..	..	..	..	36	410	1,300	1,772
12	Ditto *Ragi* transplanted alternately 9 in. apart on the same ridge.	..	..	..	..	32	496	1,297	1,026
Significance by 'Z' test			Yes	Yes	Yes				No
Critical difference			7·00	271	1·96				
Conclusions—									
1941 cold weather			mortality		3, 1, 5, 4, 2, 10				
1942 Do			Do		1, 11, 8, 2, 6, 7, 9, 10, 12				
1941 Do			kapas yield		10, 1, 2, 4, 5, 3				

N.B.—Cotton 3 ft. × 4 in. contains approximately 40,000 plants per acre which is the average population in major portions of winter Cambodia.

TABLE XII

Particulars	No. of plants examined	Mean length in cm.							
		Hypocotyl		First internode		Second internode		Third internode	
Free . .	17	6·18	±0·36	3·83	±0·24	2·25	±0·08	2·58	±0·04
Galled . .	30	5·93	±0·28	3·44	±0·12	2·28	±0·11	2·58	±0·10
Gummed .	64	6·55	±0·22	3·70	±0·12	2·32	±0·09	2·53	±0·06

(iv) Cork formation

In the course of studies on stem hairiness, *Buganda* cotton was noticed to develop cork at the regions where the hairs were shed. Co2 and many other varieties, formed cork up to the third node while in *Bourbon*, the formation was confined to the first node alone. A search, made among the varieties to find whether those that produced cork quickly withstood the insect attack best, showed that inspite of differences in the extent of suberization, no relation existed between cork formation and resistance to weevil attack.

The above trials indicated that morphological characters and agronomic devices were of no avail in checking the attack of the weevil. The only line of pursuit, likely to yield some useful and practical results, would appear to be the factor of gum formation in the South American group, its variation with regard to varieties or seasons, and its inheritance.

SUMMARY

1. Studies on host resistance of cotton indicated, that the resistant varieties were able to engulf and disintegrate the burrowing larvae of (*Pempherulus affinis*) in the gummy exudate released at the affected regions. Two South American varieties *Verdao and Peruvian*, belonging to *Gossypium barbadense* group and *Moco* from the *Gossypium purpurescens* group, were found to be highly resistant under conditions of heavy artificial infestations.

2. Two varieties, viz., *Bourbon* from *Gossypium purpurescens* group and *Nadam* classified under *G. arboreum var typicum*, were found to be tolerant and able to withstand the damage by quick repair of the affected regions.

3. Other irrigated cotton varieties were susceptible in varying degrees and succumbed to the attacks. The local variety (strain Co2) though susceptible, was superior to other resistant varieties in yield, habit and boll characters.

4. Reselection for resistance in strain Co2, did not prove fruitful.

5. Among the several interspecific hybrids, made with the South American types and studied, resistance was lowered when more than one dose of the recurrent susceptible parent was given. *Moco* and *Bourbon* varieties proved to be the best parents for imparting resistance.

6. Two derivatives, *i.e.*, 7176 and 7178 from *Moco* cross and family 4413 from *Bourbon* cross, though highly resistant, fell short of the local variety in other economic characters.

7. Improvements in quality were therefore attempted through further crossing the resistant derivatives with the latest local strains. This method of slow building up, proved to be a promising line of approach.

8. Finally, four hybrid derivatives were evolved, but they did not satisfy the requirements of both the winter and summer planting at Coimbatore and Srivilliputtur respectively. The best of them, viz., X-82-1-5 when subjected to reselection, improved in habit and productivity but not in lint quality or adjustability to the two seasons of sowings. Further crossings with long stapled quality strains had to be done to eliminate the defects.

9. Thus, while it was possible to breed for resistance, the simultaneous synthesis of quality with resistance, was a difficult task requiring a slow transference of one or two genes at a time.

10. Remedial measures, designed to utilize the known peculiarities in the habits of the insect were of no avail. Earthing up of the basal regions of the stem to obstruct oviposition, close spacing to cut off light and crop mixtures to mask plant odour, did not reduce the infestation of the insect or the extent of mortality.

11. No relation appeared to exist between morphological characters, like short internodes or degree of suberization with host resistance.

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STUDIES ON RUSTS OF SOME OF THE WILD GRASSES OCCURRING IN THE NEIGHBOURHOOD OF SIMLA*

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It is unnecessary to lay stress on the importance of the study of rusts of wild grasses as some of them have proved to be collateral hosts of one specialized form or another of the rusts of cereals. Early infection of wild grasses with black rust due to their nearness to barberry bushes, is a factor of outstanding importance in the dissemination of that rust to fields under cultivation in some of the temperate countries. Considerable amount of information is, therefore, available in literature concerning the reaction of a large number of grasses to the important cereal rusts and their natural infection in most of the European countries and in the United States, Canada and Australia.

In India, the record is rather meagre and the scanty information available is too vague about the 'specialized form' of the cereal rust involved in the natural infection of wild grasses. In earlier works there are no experimental data concerning the suspected connection of rusts of wild grasses with the cereals. Thus, Butler [1918] and Butler and Bisby [1931] have recorded the occurrence of *Puccinia graminis* (Pers.) on three wild grasses, viz., *Festuca gigantea*, *F. kashmiriana* and *Brachypodium sylraticum* but there is no information regarding the specialized form of the rust to which each of the collection belonged. Similarly, *Puccinia glumarum* (Schm.) (Erikss.) and (Henn.) has been reported by them to occur on leaves of *Phalaris minor* and *Brachypodium sylraticum* but it is not known if the rust from these grasses could infect wheat or barley. Only recently, during the course of investigations on cereal rusts in India, as recorded by Mehta [1940], it was demonstrated by inoculation experiments that the black rusts found on *Bromus patulus* and *Brachypodium sylraticum* in the neighbourhood of Simla is able to infect wheat and barley but not oats, and that yellow rust from a species of *Agropyron* does not infect either wheat or barley. It was also stated that there is no evidence to show that these rusts are propagated from one season to another on any of these grasses.

According to Mehta [1940] wheat rusts are able to oversummer in the uredo stage only in the hills of India and the uredospores disseminated by wind, cause fresh outbreaks on the crops in the plains year after year. The present investigation was started at the suggestion of Dr Mehta to find out if any of the other wild grasses, growing near Simla, is able to 'carry over' the uredo stage of black or yellow rust of wheat from one season to another.

In this article, the writer gives a short account of studies carried out by intensive observations on wild grasses for black and yellow rusts in the neighbourhood of Simla throughout the year and specially during the critical period. The 'specialized form' of rust was determined by inoculating seedlings of wheat, barley, rye and oats with pure cultures. In addition, seedlings of some of the common grasses occurring in the Simla hills were inoculated in the greenhouse with pure cultures of *Puccinia graminis tritici*, *P.g. avenae*, *P.g. secalis* and *P. glumarum* to see if they are susceptible to any of these rusts.

Review of literature

In a recent monograph by Lehmann, Kunener and Dannenmann [1937] literature on the black rust of grasses has been reviewed at length, and Fischer and Levine [1941] have given a summary of data available on the reaction of wild and cultivated grasses to *P. graminis*, *P. triticina*, *P. glumarum* and *P. coronata* in the United States and Canada with a bibliography of 93 publications. It is

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unnecessary, therefore, to discuss the earlier work of different investigators on various phases of the problem in Europe and America, and only a brief reference to more recent work done elsewhere is made here. It might be added that only a few of these studies were devoted to the rusts of grasses primarily ; in most of them the grasses have come up more or less incidentally on account of their importance as agents in the spread and overwintering of cereal rusts.

Waterhouse [1929] observed that in Australia *P. graminis tritici* is present in viable uredospore stage on *Hordeum murinum* and *Agropyron scabrum* throughout the year. He also reported the presence of *P. graminis avenae* on some grasses, chiefly on *Festuca bromoides*, *Phalaris minor* and *Hordeum murinum*. Marchal and Steyaert [1929] reported the presence of *P. graminis* on *Panicum maximum* in Belgian Congo. Marchionatto [1931] reported that yellow rust is found on *Bromus unioloides* and *Hordeum jubatum*, whence infection readily spreads to the cultivated wheat in Argentina. In South Africa Verwoerd [1931] found that physiologic race 34 of *P. graminis tritici* attacks *Hordeum murinum* and *Dactylis glomerata* and *Bromus patulus* is liable to infection by race 100. He found race 3 of *P. graminis avenae* on *Avena fatua* and *D. glomerata*, while race 2 on *Hordeum murinum*, *Avena fatua* and *D. glomerata*. Hassebrauk [1932] inoculated 182 grasses of German and foreign origin with *P. glumarum tritici* 4 and *P. graminis tritici* and observed considerable differences in the reactions of the same species of grasses from different localities to the same race, thus suggesting, that the host ranges of the various races are liable to overlap in many cases. Unamuno [1933] reported that leaves of *Lolium perenne* and *L. rigidum* were attacked by *P. glumarum* in Spain. Gassner and Straib [1934] found seven races of *P. glumarum* capable of infecting *Elymus junceus*, in Germany. Straib [1935] inoculated 227 grasses with three physiologic forms of *P. Glumarum* corresponding to *hordei* Erikss, *tritici* Erikss, and the third occupying an intermediate position. A number of these grasses including *Bromus tectorum*, *Hordeum jubatum* and *Agropyron repens* proved to be susceptible to all the three and he did not find any justification for the retention of the ' forme speciales '. Verwoerd [1935] isolated race 99 of *P. graminis tritici* from *Lolium italicum* in South Africa. Becker and Hart [1939] noticed that *Agropyron caninum* is susceptible to yellow rust in the greenhouse and is also found infected naturally in the Eastern Harz (Germany). They found that the rust from *A. repens* and *A. caninum* can infect barley.

Methods of study

Regular observations were made in the neighbourhood of Simla, and lower and higher altitudes (up to Narkunda, altitude 9,200 ft. on Hindustan-Tibet Road) of Simla hills were also visited two to three times a year.

The rusted grasses were kept in separate envelopes after collection and brought to the laboratory. If the grass was found flowering, it was collected and named, otherwise the plants were marked and identified later when the flowers were available. In every case where seed of the rusted grass could be had, the rust was multiplied on that grass for two to three generations in order to have a pure culture before inoculating the cereals. This was very necessary, specially during the time when wheat and barley crops were also found rusted simultaneously in nature. By taking this precaution all chances of coming to erroneous conclusions due to the probable presence of foreign spores in the inoculum were eliminated.

If the grass seed was not available at the time of rust collection, inoculation had to be made directly on the cereals and a culture was maintained in case any one of them got infected. The original grass host was cross-inoculated with this culture when its seed was available, to be absolutely sure of its reaction. The physiologic race of the rust was determined on standard differential hosts, selected by Stakman and Levine [1922] for *P. graminis tritici*, Stakman, Levine and Bailey [1923] for *P.g. avenae*, Levine and Stakman [1923] for *P.g. secalis* and Gassner and Straib [1932 ; 1934, 1 and 2] for *P. glumarum*, respectively.

In addition to observations on rusted grasses occurring in nature and inoculations on cereals therefrom, some of the common grasses found in the Simla hills were inoculated in the greenhouse with uredospores of *P. graminis tritici*, *P. graminis avenae*, *P. g. secalis* and *P. glumarum*, separately, in order to see if any of them could get infected under optimum conditions. Only a very small number of grasses could be inoculated in the present study and it is very essential to continue this on other genera and species.

On account of the difficulty of identification of grasses locally and collection of pure seed with the facilities available, seed of some of them was obtained from the Welsh Plant Breeding Station, Aberystwyth ; the Forest Botanist, Dehra Dun and Mycologist, Government of Madras, Coimbatore. Some grasses, seed of which could not be had, were transplanted in 8 inch pots and inoculated in the adult stage. They were kept under observation for a period of one month after inoculation to make sure of their reaction against rust.

The plants to be inoculated were raised from seed in 4 inch pots in a spore-proof greenhouse where no rust was kept. Inoculations on cereals, viz., wheat, barley, rye and oats, were made on the first leaves of the seedlings and in those greenhouses where the rusts concerned in inoculation were not maintained. Usual precautions of disinfecting the hands and instruments were taken before every inoculation. Only fresh material was used and the viability of uredospores determined by germination tests.

The following varieties of cereals were used :

1. *Wheat*—Agra local, a susceptible, unimproved *desi* variety, reported by Mehta [1940] to be heavily infected by all the physiologic races of *P. graminis tritici* and *P. glumarum*.
2. *Barley*—Agra local, a susceptible, unimproved *desi* variety, also very susceptible.
3. *Oats*—Agra local, susceptible *desi* variety.
4. *Rye*—Lyallpur grown susceptible variety and Petkusar.

For inoculating the wild grasses in the greenhouse, material of following physiologic races of each of the rusts that have been found in this country was used in mixtures in equal quantities :

1. *P. graminis tritici*—15, 21, 24, 34,* 40, 42 and 75.
2. *P. graminis avenae*—3, 4, 6 and 7.
3. *P. graminis secalis*—has not been found to occur in this country. A collection was obtained through the courtesy of Prof. F. T. Brooks of the Cambridge University and its culture maintained in the greenhouse on rye.
4. *P. glumarum*—13, 19, 20, 31, A, D, E, F, G* and H.*

Rusts of wild grasses

(A) *Black rust* Puccinia graminis (*Pers*)

(1) *Bromus patulus*, Mert. and Koch. was found infected with black rust in the uredo stage, simultaneously with the rusted wheat crop during May to June at higher altitudes (8,000—9,000 ft.) in the Simla hills. The grass is an annual and ripens with the wheat crop. By July to August, all aerial parts are dried up and there is no evidence of an oversummering of black rust on this grass.

Its pure culture was established on Agra local wheat and yielded race 15 of *P. graminis tritici*. Mehta [1940] recorded the presence of races 15, 40 and 42 on this grass.

No evidence could be obtained of the propagation of rust on this grass from one season to another or the grass getting infected earlier than wheat or barley crops.

(2) *Poa nemoralis* Linn. was for the first time found infected with *P. graminis* in the neighbourhood of Simla in July (1940), and the uredo stage was available till the end of December when the aerial parts dried up.

* These races have been found since the publication of Mehta's monograph (1940).

Since the grass is perennial, the roots produce fresh leaves year after year with the onset of rains in July when the rust also re-appeared at the same place in 1941 and 1942. Later on it was found that the rust overwinters in the uredo stage on old leaves in moist places and the new leaves, as they appear in July, get infected from them during the favourable monsoon weather. The teleuto stage has not been observed so far either in nature or in greenhouse cultures.

Inoculations made on Agra local wheat, barley, oats and rye along with *Poa trivialis* L., *P. pratensis* and *P. nemoralis* resulted only in the infection of the three species of *Poa*. The pure culture of this rust grown in the greenhouse on *Poa nemoralis* for several generations, aswell as material collected from nature, were put on differential hosts of *P. graminis tritici*, *P. g. avenae* and *P. g. secalis* but none of the varieties got infected.

The following wild grasses were also inoculated in the seedling stage with this rust :

1. Bromus patulus
2. Brachypodium sylvaticum
3. Avena fatua
4. Dactylis glomerata
5. Agrostis alba
6. Phalaris minor
7. Festuca ovina
8. Panicum crus-galli
9. Aira flexuosa
10. Aegilops caudata
11. Agropyron repens var. aristatum
12. A. semicostatum
13. A. longearistatum
14. Poa trivialis
15. P. pratensis
16. P. nemoralis

With the exception of the three species of *Poa*, none of the grasses got infected. On the basis of its reaction on varieties of wheat, barley, rye and oats as well as the grasses mentioned above, the rust under study could only be placed under the ' specialized form ' *P. graminis poae* Pers. Erikss. and Henn. ref. Grove [1913], Stakman and Levine [1924], Arthur [1929].

One hundred uredospores were measured in water under the high power and found to be 18·96 to 28·44×14·22 to 18.96μ in size and majority of them measured 23·7×16·59μ. According to Stakman and Levine [1924] the uredospores' from *Poa compressa* measure 15 to 23×13 to 18μ.

This is the first record of the occurrence of black rust on *Poa* and of the ' specialized form ' *P. graminis poae* in India.

Cross inoculations made on *Poa trivialis*, *P. pratensis* and *P. nemoralis* with *P. graminis tritici*, *P. g. avenae* and *P. g. secalis* gave negative results.

Although a black rust has been found on *Poa nemoralis* from the time of harvest of wheat crop to its next sowing, it would be apparent from the results described above that it could not be responsible for fresh outbreaks, because the rust of *Poa* does not infect wheat.

(3) *Agropyron semicostatum* Nees and *A. longearistatum* Boiss.

Black rust found on these grasses has been studied in detail and the results are recorded in a separate article and only a brief account is given here.

Heavily infected plants of *A. semicostatum* were found for the first time in this country at Taradevi (altitude 5,000 ft., six miles south-west of Simla) on 15 September, 1940. Only the teleuto stage was present at that time but next year the uredo stage was found on 23 July. A culture of the rust was established on seedlings of *A. semicostatum* in the greenhouse at Simla.

By the end of September the rust at Taradevi had all passed to the teleuto stage. Since its discovery at Taradevi the rusted grass has been observed at several places in the neighbourhood of Simla and specially near diseased bushes of *Berberis lycium* and *B. aristata*. In October, 1941, dried up

plants of *Agropyron* were noticed in the higher altitudes of Simla hills at Theog (7,500 ft.), Mattiana (7,900 ft.) and Narkunda (9,200 ft.) bearing the teleuto stage of the rust.

Infected plants of *A. longearistatum* were found at Jaku near Simla.

Uredospores from pure cultures of the rust maintained in the greenhouse on its original host were put on Agra local wheat, barley, oats and rye but no infection was produced. Differential hosts of *P. graminis tritici*, *P. g. avenae* and *P. g. secalis* also did not get infected.

The sixteen wild grasses tested against *P. graminis poae*, already described, were inoculated with this rust also. With the exception of *Bromus patulus* and the three species of *Agropyron* no other grass was infected. On the basis of its reaction on different varieties of wheat, rye and oats as well as the grasses mentioned above, the *Agropyron* rust cannot be placed under any of the known specialized forms of *P. graminis*: Grove [1913], Stakman and Piemeisel [1917], Stakman and Levine [1924], Arthur [1929]. Reasons for creating a separate form and calling it *P. graminis agropyri* Pers. Mehta and Prasada, have been fully discussed in another article dealing with this rust.

Nearly 300 uredospores were studied from three generations and found to measure 20·43 to 31·78×12·48 to 18·61μ.

Neither Butler and Bisby [1931] nor Mundkur [1938] have recorded the presence of *P. graminis* on *Agropyron* in this country and this should be considered a new record.

(B) *Yellow rust* Puccinia glumarum

(1) *Agropyron semicostatum*, Nees. was found infected at Sanahan (Simla) on 26 August, 1941. The plants were flowering at the time of collection. Mehta [1940] reported this rust on a species of *Agropyron* and stated that wheat or barley could not be infected.

Agra local wheat, barley, oats and rye were inoculated along with *Agropyron semicostatum* with uredospores collected from fields. Only *Agropyron* got infected. Since then, a culture has been maintained on it in the greenhouse.

When differential hosts of *Puccinia glumarum* were inoculated with the pure culture maintained on *Agropyron* for several generations, some infection (2 to 3 type, moderate susceptibility) was produced on five leaves out of 14 of *Triticum dicoccum tricoccum* only. No other variety was infected. The collection does not resemble in its parasitic behaviour with any of the known physiologic races, Indian or foreign, and should be considered a new race of *P. glumarum*.

Differential hosts of *P. graminis tritici* and *P. triticina* also did not get infected.

The sixteen grasses tested against the black rust of *Poa* and *Agropyron* were also inoculated but apart from three species of the latter, moderately heavy infection was produced only on *Aegilops caudata*.

Cross inoculations, made with a mixture of Indian physiologic races of wheat yellow rust, resulted in heavy infection of all the three species of *Agropyron*.

(2) *Phalaris minor* Retz. was found infected with yellow rust at Arki (lower Simla hills, altitude 3,200 ft.) on 16 April, 1942. The plants were found growing with the wheat crop also infected with yellow rust. Since the seed was not available, a pure culture could not be established on that grass and the rust was put directly on Agra local wheat, barley, oats and rye. A very light infection was produced only on two leaves of wheat out of 12 inoculated but the rust was lost in the second generation. As already stated, the inoculum was not pure and since the grass was growing along with infected wheat, it is difficult to say if it was the rust from grass or foreign spores from wheat crop sticking to it that were responsible for infection of wheat in the greenhouse. It might be stated here that *Phalaris minor* could not be infected with yellow rust of wheat in the greenhouse.

In 1943, when the seed of *Phalaris minor* was available, a pure culture of its rust was established on this grass for three generations. Inoculations made on wheat with pure culture gave negative results showing that the rust is not connected with wheat.

Puccinia glumarum has been reported on *Phalaris minor* in this country from Lyallpur, Hissar and Dehra Dun by Butler and Bisby [1931].

(3) A species of *Aegilops* was found infected with yellow rust at the Wheat Breeding Station, Simla, on 27 April, 1940. The rust was put directly on Agra local wheat, barley, oats and rye for want of seed of *Aegilops*. Heavy infection was produced only on wheat and barley seedlings. The culture was maintained on wheat and seedlings of *Aegilops* were inoculated with uredospores when the seed was available, resulting in heavy infection. The rust collection proved to be the new race A of *Puccinia glumarum* : Mehta [1940].

Inoculations made with yellow rust of wheat resulted in the infection of this grass.

This is the first record of the infection of *Aegilops* with yellow rust in this country. The grass has not been found to occur in nature in India and was cultivated at the Wheat Breeding Station, from imported seed for experimental work.

Infection of grasses in the greenhouse

Results of inoculations made on a number of wild grasses, some raised from seed and others transplanted with uredospores of *P. graminis tritici*, *P. g. avenae*, *P. g. secalis* and *P. glumarum*, are given in Tables I to IV.

Table I

Results of inoculations on some common grasses with uredospores of Puccinia graminis tritici (*a mixture of physiologic races 15, 21, 24, 34, 40, 42 and 75*)

Sr. No.	Plants inoculated	No. of trials	Result*	Infection	Nature of infection
	(*A*) *Raised from seed*				
1	Panicum crus-galli	3	0/40	—	
2	Polypogon monspeliensis	3	0/38	—	
3	Festuca pratensis	3	0/42	—	
4	Festuca rubra	3	0/36	—	
5	Festuca ovina	3	0/40	—	
6	Festuca arundenacea	3	0/37	—	
7	Festuca elatior	3	0/36	—	
8	Lolium perenne	3	0/40	—	
9	Lolium italicum	3	0/33	—	
10	Lolium temulentum	3	0/40	—	
11	Aira caespitosa	3	0/36	—	
12	Aira flexuosa	3	0/36	—	
13	Poa trivialis	3	0/35	—	
14	Poa pratensis	3	0/39	—	
15	Phleum pratense	3	0/40	—	
16	Phalaris tuberosa	3	0/33	—	
17	Phalaris minor	3	0/38	—	
18	Phalaris paradoxa	3	0/30	—	
19	Dactylis glomerata	3	5/32	+	Weak; small pustules (R)

TABLE I—*contd.*

Sr. No.	Plants inoculated	No. of leaves	Ratio*	Infection	Nature of infection
	(A) Raised from seed—contd.				
20	Agrostis alba	3	0/27	—	
21	Andropogon annulatus	3	0/39	—	
22	Andropogon contortus	3	0/40	—	
23	Brachypodium sylvaticum	2	19/24	+	Moderate (S)
24	Agropyron longearistatum	2	18/18	+	Heavy (S)
25	Agropyron semicostatum	2	20/20	+	Heavy (S)
26	Agropyron repens var. aristatum	2	16/16	+	Moderate (S)
27	Aegilops caudata	1	8/8	+	Moderate (S)
28	Avena aspera	2	0/18	—	
29	Avena fatua	2	0/18	—	
30	Bromus pectinatus	2	29/29	+	Heavy (S)
31	Eragrostis nigra	3	0/27	—	
	(B) Transplanted				
32	Festuca gigantea	1	3/10	—	Weak (R)
33	Festuca myuros	1	5/10	—	Weak (R)
34	Lolium perenne	1	0/8	—	
35	Andropogon distans	1	0/10	—	
36	Avena aspera	1	0/8	—	
37	Poa nemoralis	1	0/10	—	
38	Panicum flavidum	1	0/12	—	
39	Cynodon dactylon	1	0/10	—	

*The denominator indicates the number of leaves inoculated and the numerator indicates the number which developed rust pustules.

(S) represents susceptibility and (R) resistance. '+ and —' indicate 'positive and negative' infection, respectively.

TABLE II

Results of inoculations on some common grasses with uredospores of Puccinia graminis avenae *(a mixture of physiologic races 3, 4, 6 and 7)*

Sr. No.	Plants inoculated	No. of trials	Result	Infection	Nature of infection
	(A) Raised from seed				
1	Panicum crus-galli	2	0/23	—	
2	Polypogon monspliensis	2	0/24	—	
3	Festuca pratensis	2	0 20	—	
4	Festuca rubra	2	0 24	—	
5	Festuca ovina	2	0 30	—	
6	Festuca arundenacea	2	0 26	—	
7	Festuca elatior	2	0/24	—	
8	Lolium perenne	2	0 24	—	
9	Lolium italicum	2	0 22	—	
10	Lolium temulentum	2	4/23	+	Weak (R)
11	Aira caespitosa	2	0 24	—	
12	Aira flexuosa	2	0/23	—	
13	Poa trivialis	2	0/24	—	
14	Poa pratensis	2	0 22	—	
15	Phleum pratense	2	0 20	—	
16	Phalaris tuberosa	2	0 24	—	
17	Phalaris arundenacea	2	0 22	—	
18	Phalaris minor	2	20 20	+	Moderate (S)
19	Dactylis glomerata	2	2 22	+	Weak (R)
20	Agrostis alba	2	4 24	+	Weak (R)
21	Andropogon annulatus	2	0 24	—	
22	Andropogon contortus	2	0 22	—	
23	Brachypodium sylvaticum	2	0 20	—	
24	Agropyron longearistatum	1	15/15	+	Weak, minute pustules (R)
25	Agropyron semicostatum	1	15/15	+	Weak, minute pustules (R)
26	Agropyron repens var. aristatum	1	4 14	+	Weak, minute pustules (R)
27	Aegilops caudata	1	8/8	+	Weak, minute pustules (R)
28	Avena aspera	1	10 10	+	Moderate (S)
29	Avena fatua	1	12 12	+	Moderate (S)
30	Bromus patulus	2	24 30	+	Weak (R)
31	Eragrostis nigra	2	0 24	—	
	(B) Transplanted				
32	Festuca gigantea	1	0 10	—	
33	Festuca myuros	1	0 8	—	
34	Andropogon distans	1	0 6	—	
35	Lolium perenne	1	0 8	—	
36	Avena aspera	1	6 8	—	Moderate (S)
37	Poa nemoralis	1	0/8	—	
38	Panicum flavidum	1	0/8	—	
39	Cynodon dactylon	1	0/8	—	

TABLE III

Results of inoculations on some common grasses with uredospores of Puccinia graminis secalis *(a collection received from Cambridge)*

Sr. No.	Plants inoculated	No. of trials	Result	Infection	Nature of infection
	(A) Raised from seed				
1	Panicum crus-galli	2	0/24	—	
2	Polypogon monspeliensis	2	0/20	—	
3	Festuca pratensis	2	0/22	—	
4	Festuca rubra	2	0/24	—	
5	Festuca ovina	2	0/25	—	
6	Festuca arundenacea	2	0/22	—	
7	Festuca elatior	2	0/24	—	
8	Lolium perenne	2	0/24	—	
9	Lolium italicum	2	0/23	—	
10	Lolium temulentum	2	0/24	—	
11	Aira caespitosa	2	0/24	—	
12	Aira flexuosa	2	0/22	—	
13	Poa trivialis	2	0/18	—	
14	Poa pratensis	2	0/20	—	
15	Phleum pratense	2	0/22	—	
16	Phalaris tuberosa	2	0/18	—	
17	Phalaris arundenacea	2	0/22	—	
18	Phalaris minor	2	0/24	—	
19	Dactylis glomerata	2	3/25	+	Weak, v. minute pustules (R)
20	Agrostis alba	2	0/24	—	
21	Andropogon annulatus	2	0/22	—	
22	Andropogon contortus	2	0/23	—	
23	Brachypodium sylvaticum	2	0/24	—	
24	Agropyron longearistatum	1	18/18	+	Heavy (S)
25	Agropyron semicostatum	1	16/16	+	Heavy (S)
26	Agropyron repens var. aristatum	1	15/15	+	Heavy (S)
27	Aegilops caudata	1	8/8	+	Weak, minute pustules and flecks (R)
28	Avena aspera	2	0/18	—	
29	Avena fatua	2	0/20	—	
30	Bromus patulus	2	20/20	+	Moderate (S)
31	Eragrostis nigra	2	0/18	—	
	(B) Transplanted				
32	Festuca gigantea	1	0/8	—	
33	Festuca myurus	1	0/8	—	
34	Andropogon distans	1	0/6	—	
35	Lolium perenne	1	0/7	—	
36	Avena aspera	1	0/6	—	
37	Poa nemoralis	1	0/10	—	
38	Panicum flavidum	1	0/6	—	
39	Cynodon dactylon	1	0/8	—	

TABLE IV

Results of inoculations on some common grasses with uredospores of Puccinia glumarum *(a mixture of physiologic races 13, 19, 20, 31, A, D, E, F, G & H*

Sr. No.	Plants inoculated	No. of trials	Result	Infection	Nature of infection
	(A) Raised from seed				
1	Panicum crus-galli	2	0/22	—	
2	Polypogon monspeliensis	2	0/18	—	
3	Festuca pratensis	2	0/22	—	
4	Festuca rubra	2	0/22	—	
5	Festuca ovina	2	0/24	—	
6	Festuca arundenacea	2	0/18	—	
7	Festuca elatior	2	0/23	—	
8	Lolium perenne	2	0/24	—	
9	Lolium italicum	2	0/24	—	
10	Lolium temulentum	2	0/24	—	
11	Aira caespitosa	2	0/22	—	
12	Aira flexuosa	2	0/18	—	
13	Poa trivialis	2	0/22	—	
14	Poa pratensis	2	0/24	—	
15	Phleum pratense	2	0/18	—	
16	Phalaris tuberosa	2	0/24	—	
17	Phalaris arundenacea	2	0/24	—	
18	Phalaris minor	2	0/20	—	
19	Dactylis glomerata	2	3/23	+	Weak, mostly necrotic fleck (R)
20	Agrostis alba	2	0/24	—	
21	Andropogon annulatus	2	0/22	—	
22	Andropogon contortus	2	0/23	—	
23	Brachypodium sylvaticum	2	0/24	—	
24	Agropyron longearistatum	2	24/24	+	Heavy (S)
25	Agropyron semicostatum	2	24/24	+	Heavy (S)
26	Agropyron repens var. aristatum	2	15/24	+	Weak to moderate (R—S)

TABLE IV—*contd.*

Sr. No.	Plants inoculated	No. of trials	Result	Infection	Nature of infection
	(A) Raised from seed				
27	Aegilops caudata	1	10/10	+	Heavy (S)
28	Avena aspera	2	0/22	—	
29	Avena fatua	2	0/22	—	
30	Bromus patulus	2	24/24	+	Heavy (S)
31	Eragrostis nigra	2	0/18	—	
	(B) Transplanted				
32	Festuca gigantea	1	0/8	—	
33	Festuca myuros	1	0/8	—	
34	Andropogon distans	1	0/6	—	
35	Lolium perenne	1	0/8	—	
36	Avena aspera	1	0/7	—	
37	Poa nemoralis	1	0/8	—	
38	Panicum flavidum	1	0/5	—	
39	Cynodon dactylon	1	0/6	—	

CONCLUSIONS AND DISCUSSION OF RESULTS

Artificial infection was produced on the following grasses with uredospores of *Puccinia graminis tritici :*

Bromus patulus, Brachypodium sylvaticum, Agropyron longearistatum, A. semicostatum, A. repens var. *aristatum* and *Aegilops caudata. Dactylis glomerata, Festuca gigantea* and *F. myuros* were only weakly infected.

Dactylis glomerata, Agropyron semicostatum, A. longearistatum, A. repens var. *aristatum* and *Argilops caudata* have been infected with *P. glumarum,* the first one rather weakly. Except *Aegilops caudata,* all of them are indigenous.

In nature, *P. graminis* has been found on *Bromus patulus, Agropyron semicostatum, A. longearistatum* and *Poa nemoralis.* Yellow rust has been noticed on *A. semicostatum* and *Phalaris minor.* Amongst the indigenous grasses only the black rust found on *Bromus patulus* was able to infect wheat and barley. This grass is an annual and has been found infected along with wheat crop.

SUMMARY

During the course of these studies *Puccinia graminis* was found on *Bromus patulus, Agropyron semicostatum, A. longearistatum* and *Poa nemoralis.* The rust from *Bromus patulus* infected wheat and barley but those from the two species of *Agropyron* and *Poa* failed to do so and proved to be *Puccinia graminis agroovri* and *P. g. poae* respectively. *Puccinia glumarum* occuring on *Agropyron semicostatum* and *Phalaris minor* also did not infect wheat or barley.

Inoculated artificially with *Puccinia graminis tritici, Agropyron longearistatum, A. semicostatum* and *Bromus patulus* got heavily infected. *Brachypodium sylvaticum* and *Agropyron repens* were moderately infected and *Dactylis glomerata, Festuca gigantea* and *F. myuros* showed weak infection.

Puccinia graminis avenae infected *Avena aspora*, *A. fatua* and *Phalaris minor* moderately, and *Lolium temulentum*, *Dactylis glomerata*, *Agrostis alba*, *Agropyron longearistatum*, *A. semicostatum*, *A. repens*, *Aegilops caudata* and *Bromus patulus* weakly. *Puccinia graminis secalis* infected *Agropyron longearistatum*, *A. semicostatum* and *A. repens* heavily, *Bromus patulus* moderately and *Dactylis glomerata* and *Aegilops caudata* weakly. *Puccinia glumarum* infected *Agropyron longearistatum*, *A. semicostatum* and *Aegilops caudata* heavily, *Agropyron repens* moderately and *Dactylis glomerata* weakly.

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SOME FUNGI FROM ASSAM, III

By S. Chowdhury, Plant Pathological Laboratory, Sylhet, Assam

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THIS is the author's third contribution to the study of Assam fungi. The collections were made during the years 1945 and 1946. In the identification of a few fungi, help was received from Mr E. W. Mason of the Imperial Mycological Institute, England : the author's thanks are due to him.

I. Archimycetes

Synchytrium collapsum Syd.

Sydow and Butler, *Ann. mycol. Berl.*, v : 510, (1907) ; Saccardo, *Syll. Fung.* xxi : 839 ; *Ann. mycol. Berl.*, x : 247, (1912).

In leaves of *Clerodendron infortunatum* Gaertn. Wahjain. S. Chowdhury. 18. viii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 128.

II. Ascomycetes

Pyrenomycetes

Acanthostoma wattii (Syd. and Butler) Theiss.

Theissen, *Beih. Bot. Centralb.* xxix, **2** *Abt.* : 45, (1912) : Theissen, *J. Bombay Nat. Hist. Soc.*, xxi : 1285 , (1912) : Sydow and Butler. *Ann. mycol. Berl.* ix : 383, (1911) as *Dimerium wattii* Syd. and Butler : Saccardo, *Syll. Fung.* xxi 256 : Theissen, *Ann. mycol. Berl.*, x : 188, (1912).

On Asterina camelliae on leaves of *Thea sinensis* L. Barkandi. S. Chowdhury. 12. xii. 45. *Herb Plant Path. Lab.* Sylhet, Assam. No. 129.

III. Basidiomycetes

Ustilaginales

Sorosporium geminellum Syd. and Butler

Ann. mycol. Berl., x : 253, (1912) : Saccardo, *Syll. Fung.* xxiii : 618 ; *Mycologia* xxii : 151, (1930).

In the inflorescence of *Andropogon* sp. Baraura. S. Choudhury. 12. xi. 46. *Herb. Plant Path Lab.* Sylhet, Assam. No. 225.

Ustilago bothriochloae-intermediae Padwick

Padwick, *Mycol. Papers, Imp. mycol. Inst. No. 17* : 5-6, (1946).

In the inflorescence of *Bothriochloa intermedia* A. Camus. Sylhet. S. Chowdhury. 13. xi. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 227.

U. consimilis Syd.

Ann. mycol. Berl., xxii ; 281. 1924 ; *Mycologia* xxii : 127. (1930) : *Ann. mycol. Berl.*, x : 249, (1912) as *Ustilago sacchari* Rabenh.

In culms of *Saccharum fuscum* Roxb. Kanaighat. S. Chowdhury. 12. ii. 46. *Herb. Plant Path. Lab.* Sylhet Assam. No. 139

U. effusa Syd.

Ann. mycol. Berl., iv : 125, (1906) ; Saccardo, *Syll. Fung.* xxi : **506** : *Mycologia* xxii : 127, (1930).

In leaf-sheaths, leaves and culms of *Vetiveria zizanioides* (L.) Nash. Kanaighat. S. Chowdhury. **12**. ii. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 140.

U. pulverulenta (Cooke and Massee) Cif.

Cifferri. *Ann. mycol. Berl.* **26** : 33, (1928) : *Grev.* xvii : 34, (1889) ; Saccardo, *Syll. Fung.* ix : 285 as *Cintractia pulverulenta* Cke. and Massee.

In ovaries of *Erianthus* sp. Nungklo, Khasi Hills. **15**. xi. 46. S. Chowdhury. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 130.

Sphacelotheca hydropiperis (Schum) de Bary

Vergl. Morph. Biol. Pilze : 187, (1884) ; Saccardo. *Syll. Fung.* vii : 499. *Ann. mycol. Berl.*, x : 253, (1912).

In ovaries of *Polygonum hydropiperis* L. Shillong. **12**. xii. 46. S. Chowdhury. *Herb. Plant Path Lab.* Sylhet, Assam and *Herb. Crypt. Ind. Orient.* New Delhi. No. 182.

Cintractia utriculicola (P. Henn.) Clinton

J. Mycology viii : 143, 1902 ; *Hedwigia* xxiv : 336. (1895) as *Cintractia leucoderma* (Berk.) P. Henn. f. *utriculicola* P. Henn.

In the inflorescence of *Rynchospora corymbosa* Dom. (syn. *R. aurea* Vahl.) Rangirkul, Kulaura. S. Chowdhury. **10**. iii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam and *Herb. Crypt. Ind. Orient.* New Delhi. No. 137.

Uredinales

Aecidium argyreiae Berk. and Broome

Saccardo. *Syll. Fung.* vii : 814 ; Sydow, *Monogr. Uredi.* iv : 129. (1923-24) ; *Ann. mycol. Berl.*, iv : 441, (1906) ; *Ann. mycol. Berl.*, x : 274, (1912).

On leaves of *Argyreia speciosa* Sweet. Dawki. S. Chowdhury. 7. xii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 132.

A. crataevae Syd.

Ann. mycol. Berl., iv : 440, (1906) : Saccardo, *Syll. Fung.* xxi : **755** ; Sydow, *Monogr. Uredi.* iv : 234, (1923-24).

On leaves of *Crataeva religiosa* Forst. Kanaighat. S. Chowdhury. **12**. xii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 133.

A. kaernbachii P. Henn.

Saccardo, *Syll. Fung.* xvi : 343 ; Sydow, *Monogr. Uredi.* iv : 130, (1923-24) ; *Ann. mycol. Berl.*, iv : 441, (1906) ; *Ann. mycol. Berl.*, x : 273, (1912).

On leaves of *Ipomoea aquatica* Forsk. Sylhet. S. Chowdhury. **19**. xi. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 136.

A. mori Barclay

Saccardo, *Syll. Fung.* xi : 221 ; Sydow, *Monogr. Uredi.* iv : 275, (1923-24) ; *J. Asiatic Soc. Bengal*, lx : 225, (1891) : *Ann. mycol. Berl.*, iv : 441, (1906) ; *Ann. mycol. Berl.*, v : 507, (1907).

On leaves of *Morus alba* L. Shillong. S. Chowdhury. **20**. vii. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 138.

A. phyllanthi P. Henn.

Saccardo, *Syll. Fung.* xvi : 345 ; Sydow. *Monogr. Uredi.* iv : 192, (1923-24) : *Ann. mycol. Berl.*, v : 505, (1907) as *Aecidium phylanthinum* Syd.

On leaves of *Kirganelia reticulata* (Poir) Baill. Syn. *Phyllanthus reticulatus* Poir. Kanaighat. S. Chowdhury. 27. xi. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 143.

A. polygoni-cuspidati Diet.

Saccardo, *Syll. Fung.* xvii : 434 ; Sydow, *Monogr. Uredi.* iv : 267, (1923-24) ; *Ann. mycol. Berl.*, iv : 441, (1906).

On leaves of *Polygonum glabrum* Willd. Kanaighat. S. Chowdhury. 27. xi. 46. *Herb. Plant Path. Lab.* Sylhet, Assam.

Cerotelium peregrina (Syd. and Butler) Arth.

Bull. Torrey Bot. Club. xlvi : 510, (1917) ; Saccardo, *Syll. Fung.* xxiii : 790 as *Kuehneola peregrina* (Syd. and Butler) Syd. : Sydow, *Monogr. Uredi.* iii : 322, (1912-15) ; *Ann. mycol. Berl.*, x : 267, (1912) as *Chrysomyxa peregrina* Syd. and Butler ; *Ann. mycol. Berl.*, xii : 79, (1914).

On leaves of *Clerodendron renosum* Wall. Wahjain. S. Chowdhury. 29. x. 46. *Herb. Plant Path. Lab.* Sylhet. No. 145.

Colcosporium inulae (Kunze) Rabenh

Saccardo, *Syll. Fung.* xvii : 461 ; Sydow, *Monogr. Uredi.* iii : 609, (1912-15) ; *Ann. mycol. Berl.*, x : 271, (1912) ; *Indian Forester* liv : 176-78, (1928).

Uredo stage on leaves of *Inula cappa* DC. Jatinga. S. Chowdhury. 7. xii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 146.

C. plectranthi Barclay

J. Asiatic Soc. Bengal, lix : 89, (1890) ; Saccardo, *Syll. Fung.* ix : 317 ; Sydow, *Monogr. Uredi.* iii : 641, (1912-15) ; *Ann. mycol. Berl.*, v : 502, (1907).

On leaves of *Ocimum* sp. Darbas. S. Chowdhury. 12. iii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 147.

Hamaspora longissima (Thuem) Koern.

Saccardo, *Syll. Fung.* vii : 750 ; Sydow, *Monogr. Uredi.* iii : 79, (1912-15) ; *Grev.* xxi : 4, (1892) ; *Ann. mycol. Berl.*, iv : 437, (1906).

On leaves of *Rubus* sp. Syndai. S. Chowdhury. 19. i. 45, *Herb. Plant Path. Lab.* Sylhet, Assam. No. 148.

Phragmidium assamense Syd.

Ann. mycol. Berl., x : 264, (1912) ; Saccardo, *Syll. Fung.* xxiii : 824 ; Sydow, *Monogr. Uredi.* iii : 150, (1912-15).

On leaves of *Rubus lasiocarpus* Smith. Shillong. S. Chowdhury. 21. xii. 46. *Herb. Plant Path. Lab.* Sylhet, Assam and *Herb. Crypt. Ind. Orient.* New Delhi. No. 183.

Puccinia arundinellae Barclay

J. Asiatic Soc. Bengal, lviii : 245. (1889) : Saccardo, *Syll. Fung.* ix : 303 ; Sydow, *Monogr. Uredi.* i : 732, (1902-04) ; *Ann. mycol. Berl.*, v : 498, (1907) ; *Ann. mycol. Berl.*, x : 261, (1912).

On leaves of *Arundinella bengalensis* Druce. Tilagarh. S. Chowdhury. 26. xi. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 149.

P. gracilenta Syd. and Butler

Ann. mycol. Berl., x : 263, (1912) : Saccardo. *Syll. Fung.* xxiii : 729.

On leaves of *Bambusa* sp. Shillong. S. Chowdhury. 2. xii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 150.

P. hydrocotyles (Link) Cke.

Saccardo, *Syll. Fung.* vii : 641 ; Sydow, *Monogr. Uredi.* i : 388, (1902-4) ; *Ann. mycol. Berl.*, iv : 432, (1906).

On leaves of *Hydrocotyle javanica* Thunb. Mahadev. S. Chowdhury. **26.** xi. 45. *Herb. Plant Path. Lab.* Sylhet, Assam, No. 151.

P. invenusta Syd.

Ann. mycol. Berl., v : 498, (1907) ; Saccardo, *Syll. Fung.* xxi : 686.

On leaves of *Phragmites karka* Trin. Burnihat. S. Chowdhury. **12.** xi. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 152.

P. lateritia Berk. and Curt.

Saccardo, *Syll. Fung.* xiv : **321** : Sydow, *Monogr. Uredi.* i : 211, (1902-4) ; *Ann. mycol. Berl.*, iv : 431, (1906) ; *Ann. mycol. Berl.*, v : 495, (1907).

On leaves of *Hedyotis rostita* Br. Wahjain. S. Chowdhury. **27.** xi. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 154.

P. melanocephala Syd.

Ann. mycol. Berl., v : 500, (1907) : Saccardo, *Syll. Fung.* xxi : 685.

On leaves of *Arundinaria subercata* Munro. Thyria. S. Chowdhury. **30.** xi. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 155.

P. phlogacanthi Syd.

Ann. mycol. Berl., ix : 143, (1911) ; Saccardo, *Syll. Fung.* xxiii : 667.

On leaves of *Phlogacanthus curviflorus* Nees. Sylhet. S. Chowdhury. **19.** x. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 157.

P. prainiana Barclay

Scient. Mem. Med. Officers Army India, vi : 67, (1891) ; Saccardo. *Syll. Fung.* xi : 197 : Sydow, *Monogr. Uredi.* i : 635, (1902-4) : *Scient. Mem. Med. Officers Army India*, iv : 37, (1889) as *Cacoma smilacinis* Barclay : *J. Asiatic Soc. Bengal*, lix : 95, (1890) as *Cacoma smilacis* Barclay : *Hedwigia* xxix : 269, (1890).

On leaves of *Smilax* sp. Shillong. S. Chowdhury. **21.** xi. 45. *Herb. Plant Path. Lab.* Sylhet. No. 158.

P. solmsii P. Henn.

Saccardo, *Syll. Fung.* xiv : 357 : Sydow, *Monogr. Uredi.* i : 568, (1902-4) ; *Ann. mycol. Berl.*, v : 496, (1907).

On leaves of *Polygonum chinense* L. Jaintapur. S. Chowdhury. **24.** ii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 159.

P. suaveolens (Link) Rostrup

Saccardo. *Syll. Fung.* vii : 633 : Sydow, *Monogr. Uredi.* i : **53**. 856, (1902-4) : *Ann. mycol. Berl.*, x : 257, (1912).

On leaves of *Cirsium lepskyle* Petral. Burnihat. S. Chowdhury. **2.** i. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 160.

Ravenelia ornata Syd.

Ann. mycol. Berl., iv : 437, (1906) ; Saccardo, *Syll. Fung.* xxi : 738 ; Sydow, *Monogr. Uredi.* iii : 234, (1912-15) : *Ann. Roy. bot. Gardn. Peradeniya* v : 238, (1912).

On leaves of *Abrus pulchellus* Wall. Mahadev. S. Chowdhury. **28.** xi. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 163.

R. sessilis Berk.

Saccardo, *Syll. Fung.* vii : 773 ; Sydow, *Monogr. Uredi.* iii : 248, (1912-15) ; *Scient. Mem. Med. Officers Army India* iv : 20-36, (1889) ; *Beih. Bot. Centralbl.* xx : 384, (1906) ; *J. Roy. Micros. Soc.* iii : 386, (1880) ; *Hedwigia*, xxxiii : 22-6, (1894) ; *Ann. mycol. Berl.*, iv : 437, (1906).

On leaves and fruits of *Albizzia lebbek* Benth. Sylhet, S. Chowdhury, **21**. iii. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 164.

Uredo acori Racib.

Saccardo, *Syll. Fung.* xvi : 357 ; Sydow, *Monogr. Uredi.* iv : 521, (1923-24) ; *Ann. mycol. Berl.*, iv : 443, (1906).

On leaves of *Acorus calamus* L. Basistha, S. Chowdhury, **2**. ii. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 165.

U. paspali-scrobiculati Syd.

Ann. mycol. Berl., iv : 441, (1906) ; Saccardo, *Syll. Fung.* xxi : 808 ; Sydow, *Monogr. Uredi.* iv : 544, (1923-24) ; *Ann. mycol. Berl.*, v : 509, (1907) ; Butler, *Fungi and Disease in Plants* : 240, (1918).

On leaves of *Paspalum scrobiculatum* L. Gowainghat, S. Chowdhury, **15**. iii. 45. *Herb. Plant Path Lab.* Sylhet, Assam. No. 167.

Hymenomycetes

Coprinus fimbriatus Berk. and Broome

Saccardo, *Syll. Fung.* v : 1105 ; *J. Asiatic Soc. Bengal, N. S.* xvi : 352, (1920).

Usually on dung. Sylhet. S. Chowdhury. **15**. vii. 45.

C. nivcus Pers Fr.

Saccardo, *Syll. Fung.* v : 1088 ; *Proc. Indian Assocn. Cult. Sci.* iv : 109-14, (1919) ; *Proc. Sci. Convcn. Indian Assocn. Cult. Sci.* (1918) : 136-43, (1920).

On dung and heaps of rotten straw. Sylhet. S. Chowdhury. **10**. vi. 45.

Daedalea boseii Lloyd

Lloyd, *Mycological Notes. No. 1-75* ; 1069, (1898-1925) ; *Proc. Sci. Convcn. Indian Assocn. Cult. Sci.* (1920-21) : 32, (1923).

On dead branches of *Mangifera indica* L. Rainagar, S. Chowdhury, **11**. xi. 46. *Herb. Plant Path. Lab.* Sylhet. No. 191.

Exobasidium assamense Syd. and Butler

Ann. mycol. Berl., x : 275, (1912) ; Saccardo, *Syll. Fung.* xxiii : 556.

On leaves of *Camellia drupifera* Lour. Dumpep, S. Chowdhury, **17**. ix. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 192.

Flammula dilepis Berk. and Broome

Saccardo, *Syll. Fung.* v : 812 ; *J. Asiatic Soc. Bengal, N. S.* xvi : 351, (1920).

Very common in stumps and holes in palms and other large trees in Assam. Sylhet. S. Chowdhury. **19**. viii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam.

Fomes adamantinus (Berk.) Sacc.

Saccardo, *Syll. Fung.* vi : 204 ; *Proc. Sci. Convcn. Indian Assocn. Cult. Sci.* for the year (1920-21), 30, (1923) : Lloyd, *Synopsis of the genus Fomes* : 235, (1915) ; *In Hooker's London J. Bot.* iii-viii, no. 426 as *Polyporus adamantinus* Berk.

On dead wood. Pynursla. S. Chowdhury. **25**. ix. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 194.

F. annosus Fr.

Saccardo, *Syll. Fung.* vi : 197 ; Hole, *A Manual of Botany for Indian Forest Students* : 195, (1909) ; *Indian Forester* liii : 435, (1927) ; *Zeitsch fur Pflanzen-kr.* xv : 48, (1905) ; *J. Dep. Sci. Calcutta Univ.* ix : 39, (1928).

At the base of stumps of pine trees, and on pine wood paling. Shillong. S. Chowdhury. **30.** x. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 195.

F. durissimus Lloyd

Lloyd, *Mycological Notes Nos. 1-75* : 1069, (1898-1925) ; *Ann. mycol. Berl.*, xix : 130, (1921).

On dead stem of *Artocarpus* sp. Ranibari. S. Chowdhury. **11.** x. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 196.

F. lamaoensis (Murr.) Sacc. and Trott.

Saccardo, *Syll. Fung.* xxi : 287 ; Lloyd, *Mycological Notes Nos. 1-75* : 1069, 1186, 1266. (1898-1925) ; *Proc. Sci. Conven. Indian. Assocn. Cult. Sci.* (1920-21) ; 29. (1923) ; *Quart. J. Indian Tea Assocn.* (1930) : i : 28, (1930) ; Butler, *Fungi and Disease in Plants* : 429, (1918) ; *Quart. J. Indian Tea Assocn. 1922*, iii : 115. (1922) ; *Ann. Rep. Mycologist, Burma yr. ending 30 June, (1925)*, 4, (1926) : *Dep. Agric. Burma Bull.* xiv : 4, (1926).

On roots of *Thea sinensis* L. Dullabcherra. S. Chowdhury. **20.** x. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 197.

F. marginatus Fr.

Saccardo. *Syll. Fung.* vi : 168 ; *In Hooker's London J. Bot.* iii-viii, after no. 427, as *Polyporus marginatus* Fr. ; *Trans. Linn. Soc.* London II *ser. Bot.* i : 123, (1874).

On dead trees. Dawki. S. Chowdhury. **15.** x. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 198.

F. semitostus Berk.

Saccardo, *Syll. Fung.* vi : 200 ; Reichardt. *Fungi Hepaticae, et Musci frondosi, in Bot. Teil Reise der Oesterreichischen Fregatte Novara um die Erde in den Jahren* (1857-59) : 140. (1870) ; Lloyd, *Synopsis of the genus Fomes* : 221. (1915) ; Lloyd, *Mycological Notes Nos. 1-75* : 1126, (1898-1925) as *Trametes semitosta.*

On dead wood. Upper Shillong. S. Chowdhury. **15.** x. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 199.

Lenzites malaccensis Sacc. and Cub.

Saccardo, *Syll. Fung.* v : 645 ; *J. Dep. Sci. Calcutta Univ.* ix : 40, (1928).

On old trunks and stumps of trees. Debpur. S. Chowdhury. **27.** vii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 201.

L. tricolor (Bull.) Fries

Saccardo, *Syll. Fung.* v : 639 ; *J. Dep. Sci. Calcutta Univ.* xi : 13, (1934) ; Mundkur, *Sci. Monogr. Imp. Coun. Agric. Res. India* xii : 27, (1938).

On trunks of trees. Shillong. S. Chowdhury. **29.** ix. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 203.

Polystictus abietinus (Dicks.) Fries

Saccardo, *Syll. Fung.* vi : 265 ; *J. Dep. Sci. Calcutta Univ.* xi : 6. (1934).

In pine forests. Shillong. S. Chowdhury. **10.** x. 46. *Herb. Plant Path. Lab.* Sylhet. No. 204.

IV. Fungi Imperfecti

Moniliales

Alternaria citri Pierce

Saccardo, *Syll. Fung.* xviii : 623 ; *Bombay Dep. Agric. Bull.* 176, (1934) : 28, (1935) ; Chaudhuri, *Indian J. Agric. Sci.* vi : 97-8, (1936).

On *Citrus sinensis* Osbeck. Ranibari. S. Chowdhury. 21. viii. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 205.

A. longipes (Ell. and Ev.) Mason

Annoted account of fungi received at the Imperial Bureau of Mycology. *List* 2. *Fasc.* 1 : 43, (1928) : Mundkur, *Sci. Monogr. Imp. Counc. Agric. Res. India* xii : 30, (1938).

On leaves of *Nicotiana tabacum* L. Sylhet. S. Chowdhury. 26. iii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 206.

Cercospora anthelmintica Atkinson

Saccardo, *Syll. Fung.* x : 636 ; *Ann. Crypt. Exot.* ii : 262, (1929-1930).

On leaves of *Chenopodium ambrosioides* L. Sylhet. S. Chowdhury. 25. ii. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 207.

C. batatae Zimm.

Saccardo. *Sylt. Fung.* xviii : 605, *Ann. Crypt. Exot.* ii : 263, (1929-1930).

On leaves of *Ipomoea batatas* Lamk. Maulvibazar. S. Chowdhury. 30. ii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 208.

C. cannabina Wakef.

Ann. Crypt. Exot. ii : 264, (1929-1930).

On leaves of *Cannabis sativa* L. Shillong. S. Chowdhury. 16. ix. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 209.

C. capsici Heald and Wolf

Ann. Crypt. Exot. ii : 264, (1929-1930).

On leaves of *Capsicum annuum* L. Kamalpur. S. Chowdhury. 22. iv. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 210.

C. oryzae Miyake

Saccardo. *Syll. Fung.* xxii : 1431 ; *Agric. Res. Inst. Pusa Bull.* xxxiv : 35, (1913).

On leaves of *Oryza sativa* L. Karimganj. S. Chowdhury. 16. x. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 213.

Fusarium solani (Mart.) App. and Wr.

Wellenweber and Reinking, *Die fusarien*, Berlin : 135, (1935) : *Int. Bull. Plant Protect.* ix : 177. 1935 ; Mundkur. *Sci. Monogr. Imp. Counc. Agric. Res. India* xii : 34, (1938).

On *Solanum tuberosum* L. Shillong. S. Chowdhury. 18. viii. 46. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 216.

F. oxysporum Schl. var. *tuberosi* (E. F. Sm.) Wollenw. and Reink.

Woollenweber and Reinking. *Die fusarien*. Berlin : 119. (1935) : Mundkur. *Sci. Monogr. Imp. Counc. Agric. Res. India* xii : 34, (1938).

On roots and corm of *Musa sapientum* L. Lakhipur. S. Chowdhury. 12. viii. 45. *Herb Plant Path. Lab.* Sylhet, Assam. No. 217.

F. bulbigenum Cke. and Mass. var. *lycopersici* (Brushi) Woollenw. and Reink.

Wollenweber and Reinking. *Die fusarien*. Berlin : 114, (1935); Mundkur, *Sci. Monogr. Imp. Counc. Agric. Res. India.* xii : 33, (1938).

On roots of *Lycopersicon esculentum* Mill. Bhadeswar. S. Chowdhury. 17. xi. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 218.

Sphaeropsidales and Melanconiales

Coniothyrium arecae Padwick and Merh

Imp. mycol. Inst. Mycol. Papers vii : 4-5, (1943).

On living leaves of *Areca catechu* L. Sylhet. S. Chowdhury. 21, viii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 219.

Cytospora bambusina Diedicke

Ann. mycol. Berl., xiv : 193, (1916).

On dead stems of *Bambusa* sp. Sylhet. S. Chowdhury. 18. vi. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 220.

Diplodia musae Diedicke

Ann. mycol. Berl. xiv : 200, (1915).

On dead fruits of *Musa sapientum* L. Samshernagar. S. Chowdhury. 25. x. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 221.

Phyllosticta pongamiae Syd.

Ann. mycol. Berl., xiv : 178, (1916).

On leaves of *Pongamia glabra* Vent. *Agna.* S. Chowdhury. 12. viii. 45. *Herb. Plant Path. Lab.* Sylhet, Assam. No. 224.

A MODIFIED KEY AND ENUMERATION OF THE SPECIES OF *ORYZA* LINN.

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THE morphology of the spikelet of rice was discussed by Chatterjee [1947] in an earlier paper. On the basis of this discussion it is necessary to modify the generic description of *Oryza* as follows :

Oryza Linn. *Sp. Pl. 333 (1753)*

Usually moderately tall, to tall, annual or perennial, terrestrial or aquatic *grasses* ; loosely to compactly tufted, sometimes rhizomatous ; *leaf blade* usually long linear to lanceolate, flat ; *ligules* membranous to scarious ; *spikelets* strongly to laterally compressed, narrowly oblong, lanceolate elliptic oblong, awn present or absent, shortly pedicelled on simple or divided branches of open or contracted panicles, rachilla disarticulating below the lower floret and not produced beyond the uppermost floret ; *florets* three ; the first two reduced to lemmas, the terminal hermaphrodite. *Glumes* two, very small and obscure reduced to a minute annular or two lobed rim on the tip of the pedicel or broadly semi-oblate, free from each other ; *sterile lemmas* two, linear to linear lanceolate, subulate or setaceous, up to half the length of the spikelet, rarely longer and very rarely absent, erect, nerveless or 1-5 nerved, scarious, subcoriaceous or finely membranous ; *fertile lemma* asymmetrical, laterally compressed and keeled, coriaceous and rigid, awnless or with a short or long straight terminal awn, 5-nerved ; *palea* narrower than and as long as the lemma or slightly longer, acuminate, cuspidate acute or obtuse, keeled, 3-nerved with lateral nerves close to the margins, coriaceous, margin membranous ; *lodicules* 2, glabrous, entire or 2-lobed ; *stamens* 6 ; *ovary* glabrous, style short free ; stigma plumose ; *caryopsis* laterally compressed, closely invested by or tightly adhering to the fertile lemma and palea ; hilum as long as the caryopsis.

Species 23, in tropical regions of Asia, Africa, Australia and America.

Key to the species of Oryza *(modified from Roschevicz)**

A. Sterile lemmas present :
B. Sterile lemmas linear or linear lanceolate :
C. Ligule of lower leaves very long, 15-45 mm. long :
D. Annuals ; leaf blades narrow, up to 1 cm. wide ; spikelets 6·5—7 mm. long, 2 mm. wide ; awns 1—5 cm. (rarely longer, up to 10 cm. long) :
E. Spikelets persistent . . . . . *sativa* (18)
E. Spikelets deciduous . . . . . *sativa* var. *fatua* (19)
D. Perennial with rhizomes, leaf blades broad, 10—20 mm. wide, spikelets about 9 mm. long, 2·5 mm. wide, awns 7-10 cm. long . . . . . *perennis* (14)
C. Ligule of lower leaves short, up to 6 mm. long :
F. Sterile lemmas almost equal in length and similar in structure to the fertile lemma and palea . . . . *grandiglumis* (8)
F. Sterile lemmas always considerably shorter than the fertile lemma and palea :
G. Fertile lemma and palea perfectly glabrous, spikelets usually awnless, panicle branches undivided . . . *glaberrima* (7)
G. Fertile lemma along keel and ribs, sometimes over whole surface, covered with scattered bristles :
H. Spikelets small, 3—4 mm. long, up to 2 mm. wide, awns equal to the spikelets or slightly longer . . *minuta* (12)

*Alternatives are indicated by having the same letter placed in front of them.

H. Spikelets 4·5—11 mm. long :
I. Awns 6—20 cm. long :
J. Spikelets not exceeding 9 mm. long, sterile lemmas 2—2·5 mm. long, awns 10—13 cm. . *stapfii* (21)
J. Spikelets 10—11 mm. long, sterile lemmas 3—5 mm. long, awns 10—20 cm. . . . *breviligulata* (4)
I. Awns not exceeding 5 cm. in length :
K. Axis of inflorescence and branches minutely ciliate . . . . . *australiensis* (2)
K. Axis of inflorescence slightly woolly pubescent at the origin of branches, the rest, entirely glabrous, smooth or scabrid :
L. Leaf blades elongate lanceolate, 3—6 cm. wide, ligule with a fringe of hair at the apex :
M. Spikelets 7·5—9 mm. long, awns 2—3 cm. long, sterile lemmas acuminate . . . *alta* (1)
M. Spikelets 5—6 mm. long, awns 1—2 cm. long, sterile lemmas acute . . . . *latifolia* (10)
L. Leaf-blades linear lanceolate, not exceeding 2 cm. in width, ligule not fringed :
N. Spikelets 6—6·5 mm. long, awns 3—7 cm. long, ligule 4—6 mm. long . . . . *punctata* (16)
N. Spikelets 4—5 mm. long, awns up to 3 cm., ligules 2—3 mm. long :
O. Panicles loose with spreading branches, spikelets broadly oblong 2·3—2·5 mm. wide . *officinalis* (13)
O. Panicles contracted with shorter ascending branches, spikelets oblong, less than 2 mm. wide . . . . . *eichingeri* (6)

B. Sterile lemmas subulate or setaceous :
P. Fertile lemma with minutely tuberculate, corrugated or verrucose surface :
Q. Spikelets 5—6·5 mm. long, ovate oblong toe elliptic-oblong *granulata* (9)
Q. Spikelets 7—9·5 mm. long, narrowly oblong to lanceolate . . . . . *meyeriana* (11)
P. Fertile lemma almost smooth with fine longitudinally dotted striped surface :
R. Awns 6—17 cm. long . . . . . *brachyantha* (3)
R. Awns either absent, or when present not longer than 1 cm.:
S. Spikelets 1.5—1.75 mm. long . . . . . *schlechterii* (20)
S. Spikelets 8—17 mm. long :
T. Lemma ciliate along keel, without wing, awn 8-10 mm. long, leaves membranous . . . . . *ridleyi* (17)
T. Lemma glabrous along keel, with wing, awn 2—4 mm. long, leaves coriaceous with prickly tuberculate margin *coarctata* (5)
B. Sterile lemmas cup shaped with 3—5 nerves, broadly clasping the base of the spikelet ; fertile lemma almost smooth, with minute longitudinally dotted-striped surface . . . *subulata* (22)
A. Sterile lemmas absent :
U. Panicle very slender almost simple ; sheath ciliate on the margin ; spikelets setigerous . . . . . *perrieri* (15)

U. Panicle branched, long exserted from the sheath, spikelet almost glabrous ... *tisserantii* (23)

ENUMERATION OF SPECIES OF ORYZA

1. O. ALTA *Swallen* in *Bot. Maya Area*, published by Carnegie Inst. of Washington, no. **461**, 156 (1936).
   DISTRIBUTION : South and Central America ;British Hondurus, Brazil and Paraguay.
2. O. AUSTRALIENSIS *Domin* in Biblioth. *Bot.* **20**, *Heft* 85. 333 (1915); Roschev. in *Bull. Appl. Bot. Genet. Pl.* Breed **27**, part 4, 45, 125 (1931) ; A. Cheval. in *Rev. Bot. Appl. et Agric. Trop.* **12**, 1016 (1932) ; C. E. Hubbard in *Hook. Icon.*3232 (1934).
   O. sativa Muell. non Linn. in *Fragm. Phyt.* Austral **8**, 115 [1873] ; *Benth.* Fl. Australia **7**, 550 [1878] ; Baily, Queens. Fl. **6**, 1844 (1902) ; Ewart and Davis, Fl. North *Territ.* 41 (1917).
   DISTRIBUTION : Australia : Western Australia, Northern Territory, Queensland.
3. O. BRACHYANTHA *A. Cheval. et Roehrich* in *Compt. Rend. Acad Sci.*Paris **159**, 561 (1914) ; Roschev l.c. 86 ; *A. Cheval.* in *Rev. Bot. Appl. et Agric. Trop* **12**, 1022 (1932).
   O. barthii A. Cheval. *pro parte.*
   DISTRIBUTION : West Tropical and Central Africa : Anglo-Egyptian Sudan.
4. O. BREVILIGULATA *A. Cheval. et Roehrich* in *Comp. Rend. Acad. Sci.* Paris **159**, 560(1914) ; Roschev l.c. 55 ; A. Cheval. in *Rev. Bot. Appl.et Agric. Trop.* **12**, 1018 [1932].
   O. barthii A. Cheval. pro parte.
   O. mezii Prodoehl in *Bot. Archiv* **1**,223 [1922] *pro parte.*
   DISTRIBUTION : West Tropical Africa to Anglo-Egyptian Sudan.
5. O. COARCTATA *Roxb.* in *Hort.* Bengl. 87 [1814] *et Fl. Ind.* **2**, 206 [1832] ; *Griff*, Notulae **3**, 8 [1851] ; *Icon. Pl. Asiat. tab* 142 [1851] ; *Miq. Fl. Ind. Bat.* **3**, 371 [1855] ; *Watt, Dict. Econ. Prod. Ind.* **5**, 504 [1891]. Hook f. in *Fl. Br. Ind.* **7**, 93 [1897] ; Prain, Bengl. Pl. **2**, 1184 [1903] ; Cooke, *Fl. Bomb.* **2**, 1042 [1908] : Prodoehl in *Bot.* Archiv **1**, 232 [1922] ; Roschev. l.c. 94 ; A. Cheval in *Rev. Bot. Appl. et Agric. Trop.* **12**, 1024 [1932].
   O. triticoides Griffith, Notulæ **3**, 8 [1851].
   Sclerophyllum coarctatum Griffith (l.c.)
   DISTRIBUTION : India ; delta area of the Indus, and Ganges (Sundarbans) Burma, delta area of Irrawadi, Tennesarrim.
6. O. EICHINGERI *Peter* in Fedde Repert. **40**, Anhang 74 [1930] *et l.c.* **40**, 251 [1931].
   DISTRIBUTION : East Africa ; Tanganiyika territory and Uganda.
7. O. GLABERRIMA *Steud. Syn. Pl. Glum.* **1**, 3 [1855] ; *Prod.* in *Bot. Archiv.* **1**, 234 [1922] ; Roschev. l.c. 58 ; A. Cheval. in *Rev. Bot. Appl. et Agric. Trop.* **12**, 1018 [1932].
   DISTRIBUTION :West Tropical Africa.
8. O. GRANDIGLUMIS (*Doell*) *Prodoehl* in *Bot.* Archiv **1**, 233 [1922] ; Roschev. l.c. 66 ; A. Cheval. in *Rev. Bot. Appl.et Agric. Trop.* **12**, 1020 (1932).
   DISTRIBUTION: South America ; Brazil.
9. O. GRANULATA *Nees et Arn. ex Hook f.* in *Fl. Br. Ind.* 7,93 [1897] ; Wight Cat. 2354 [1833] *nomen* ; *Wall. Cat.* ; 8634 *nomen* ;
   Steud. *Pl. Glum.* 1, 3(1855) *nomen* ; Prain in *Beng.* Pl. 2,1184 (1903).
   O. filiformis Buch-Ham. ex Steud. Pl. Glum. **1**, 3 [1855] *nomen.*
   O. triandra Heyne ex Steud. Pl. Glum. 1, 3 [1855] *nomen.* Hook. f., Koorders (Exkursion fl. Java **7**, 142, 1911), Merrill (*Enum. Philip Fl. Pl.* **10**, 77) and Roschev (l.c.), have united wrongly *O. meyeriana* (Zoll. et Mor.) Baill. with *O. granulata.* Fischer and Bor, apparently (l.c. infra) have followed this. The two species resemble very closely, but can be separated by the key. Backer [1946] has given further details of separating these two species.
   DISTRIBUTION : India, Assam, South India ; Ceylon ; Burma ; Java ; Siam.

10. O. LATIFOLIA *Desv.* in *Journ.* de *Bot.* **1**, 77 [1913] ; spelt *Orysa latifolia ;* H. B. K. in *Nov. Gen. et Sp.* **1**, 195 [1815] ; Steud. *Syn. Pl.* Glum. **1**, 3, [1855] ; Prod. in *Bot. Archiv* **1**, 224 [1922] Roschev. l.c. 62 ; A. *Cheval.* in *Rev. Bot. Appl. et Agric. Trop.* 12, 1018 [1932].
O. platyphylla Schult. f. in Roem et Schult. Syst. **7**, 1364 [1830].
DISTRIBUTION : Central and South America ; West Indies.

11. O. MEYERIANA (*Zoll. et Mor.*) *Baill. Hist. Pl.* **12,** 166 [1894] ; Fischer in Gamble's Flora Madras 3, 1845 [1934] *Bor.* in *Fl.* Assam **5,** 172 (1940).
Padia meyeriana Zoll. et Mor. Verzeich. *Pl. Zoll.* 103 [1846] Steud. Syn. Pl. Glum. 1, 3 [1855] ; Merrill in Philip *Journ. Sc.* **1**, *Suppl.* 370 [1906].
O. abromeitiana Prodoehl in *Bot.* Archiv **1**, 234 [1922].
DISTRIBUTION : Java ; Borneo ; Philippines ; Siam.

12. O. MINUTA *Presl.* Rel. Haenk. **1,** 208 [1830] ; *Miq. Fl. Ind. Bat.* **3,** 371 [1857] ; Prodoehl in *Bot.* Archiv **1,** 231 [1922] Roschev. l.c. 75 ; A. Cheval. in *Rev. Bot. Appl. et Agric. Trop.* **12,** 1020 [1932]; Backer in Blumea, *Suppl.* **3.**, 53 [1946].
O. manilensis Merrill in *Philip. Journ. Sc.* **3,** 219 [1908].
O. fatua Ridley non Koen. in Fl. *Mal. Penin.* **5,** 252 [1925].
DISTRIBUTION : Malay Peninsula ; Philippines ; Sumatra, Java, Borneo.

13. O. OFFICINALIS *Wall. ex Watt, Dict. Econ. Prod. Ind.* **5**, 501 [1891].
O. officinalis Wall. Cat. 8635 (*nomen*), descript. Watt (l.c.) Steud. Pl. Glum **1,** 3 [1855]-*nomen*, Prodoehl in Bot. Archiv **1**, 224 [1922] ; Bor. in Fl. Assam **5,** 171 [1940].
O. latifolia Hook. f. non Desv. in Fl. *Br. Ind.* **7,** 92 [1897].
DISTRIBUTION : India, Assam ; Burma.

14. O. PERENNIS *Moench.* in Meth. Pl. 197[1794]; *Steud.Syn.Glum.* **1**, 3 (1855); A. Cheval. in *Rev. Bot. Appl. et Agric. Trop.* **12,** 1027 [1932]. Hitchcock, Man. Grasses West Ind. 145 (1936) ; R. Ciferri in *Atti, Ser.* **5**, 7, 7(1946).
O. sativa Miller non Linn. in Mill. *Illustr. Syst. Tab.* 19 (1777).
O. longistaminata A. Cheval. et Roehr. in *Compt. Rend. Acad. Sci.* Paris 149, 561 [1914].
O. Barthii A. Chaval. *pro parte.*
O. dewildemanii Vanderyst in *Bull. Agric. Congo. Belge* **9,** 123 [1920] *nomen in syn.*
O. glumaepatula Steud. Syn. *Glum.* 1, 3 [1855].
DISTRIBUTION : Tropical America ; West Indies, *Trop. Africa ;* Ceylon.

15. O. PERRIERI *A. Camus* in *Bull. Soc. Bot.* France 73, 690 [1926].
DISTRIBUTION : Madagascar.

16. O. PUNCTATA *Kotschy ex Steud.* Syn. Pl. Glum. **1,** 3 [1855] ; Roschev. l.c. 48 ; A. Cheval. in *Rev. Bot. Appl et Agric. Trop.* **12,** 1016 [1932].
O. schweinfurthiana Prodoehl in *Bot.* Archiv 1, 231 [1922].
DISTRIBUTION : North East Tropical Africa.

17. O. RIDLEYI *Hook. f.* in Fl. *Br. Ind.* **7**, 93 [1897] Ridley in *Mat.* Fl. *Mal. Penin* **3,** 148 [1907] *et* Fl. *Mal. Penin* **5,** 251 (1925) ; Camus et Camus in Fl. Indo China **7,** 501 (1923) ; Prodoehl in *Bot.* Archiv 1, 232 (1922) ; Roschev. l.c. 91 ; A. Cheval. in *Rev. Bot. Appl. et Agric. Trop.* **12**, 1024 (1932).
O. stenothyrsus K. Schum. in Lauterbach Nachtz. Fl. Deutsch. Südsee 57, [1905] Prodoehl in *Bot.* Archiv **1,** 232, [1922] ; Roschev. l.c. 91.
DISTRIBUTION : Malay Peninsula ; Siam ; Borneo ; New Guinea.

18. O. SATIVA Linn. Sp. Pl. 333 [1753] *sensu latiore.* the widely cultivated rice.
O. aristata Blanco. Fl. Filip 274 (1837) ; *O. communissima* Lour. Fl. Cochinch. **1**,214 (1790) ; *O. denudata* Desv. ex Steud. *Nomencl.* Ed. 2,**2**,234 [1841] ; *O. glumaepatula* Steud. Syn. Pl. *Glum.* **1,** 3 (1855); *O. glutinosa* Lour. Fl. Cochinch. 215 [1790] : *O. latifolia* P. Beauv. non Desv. *Agrost.* 27 (1812) *O. marginata* Desv. et *Steud. Nomend.* **2**,577 [1821] ; *O. montana* Lour. Fl. Cochinch. 215 [1790] et Miq. Fl. *Ind. Bat.* 3, 370 [1855] *O.mutica* Lour. ex Steud *Nom.* **2,** 577 [1821] ; *O. nepalensis* G. Don. ex Steud. *Syn. Pl. Glum* **1,** 3 [1855] ; *O. palustris* Salisbury, *Prodrom.* 25 [1796]; *O. parviflora Beauv. Agrost.* 27 [1812] ; *O. praecox* Lour. Fl. Cochinch.

215 (1790) ; *O. pubescens* Desv. ex Steud. *Nom.* **2**, 577 [1821];*O. pumila* Hort. ex Steud. *Nom. Ed.* **2**, **2**. 234 [1841] ; *O. repens* Buch Ham. ex Steud. Syn. Glum 1, 3, [1855] ; *O. rubribarbis* Desv. ex Steud. Nom **2**. 577 (1821) ; *O. rufipogon* Griffith, Notulae 3, 5 [1851] et *Icon.* Pl. Asiat. **3**, *tab.* **144**, ii (1851); *O. segetalis* Russ. ex Steud. Syn. Pl. Glum 1, 3 (1855) ; *O. sorghoidea* Desv. ex Steud. Nomencl. **2**, 577 (1821) ; *O. sorghoides* Desv.ex Steud. Syn. Pl. Glum. **1**, 3 (1855).

History

The cultivated rice comprises an extremely large number of varieties and races. The great diversity of forms is baffling to the taxonomist who attempts to classify them. Both vegetative and reproductive characters have been used for classification and other characters such as floating rice, ordinary rice, colour of kernel, colour of ligule, glutinous and starchy grains, presence or absence of awn, flavour or scent after cooking. Physiological and agronomic characters have also been employed such as, early or late maturing plant and the yield per unit acres of land. The yield character although of very little significance from the taxonomist's point of view, is considered an important factor for the cultivator's selection.

Above considerations show the difficulties in the way of a general classification of the cultivated rice. In the U. S. A. all rices are grouped into three classes, *i.e.* round, medium and long. This is indeed an arbitrary grouping of convenience. Kikkawa [1912] has distinguished a few types with regard to the utility of the grain. These are glutinous and non-glutinous rice, long and short grained rice, large, medium and small grained, coloured and specially coloured grains, scented rice, shape of husked and unhusked grains and white abdomened rice. Watt [1891] in his grouping of the cultivated rice has laid stress on the locality of production and season of cultivation. Roy [1921] on the other hand classified the wild rice of the Central Provinces of India into 24 groups.

The need for a classification of varieties has been felt by many agricultural workers in all countries. It was resolved in the Rice Congress at Valencia that 'there be made in all countries a botanical study of the varieties of cultivated rice seeking a provisional classification based on the characters which may be considered fixed'. Copeland [1921] has suggested that this study should be based on three main principles, *e.g.* (i) the object of classification should be kept in mind, (ii) it should be as easy as possible to use and (iii) it should be natural, *i.e.* it should express the true genetic relationships of the varieties classified. Unfortunately our present knowledge of the varieties is insufficient to permit a near approach to a nature classification and more often a principle of convenience is used in the grouping of the varieties. Copeland [1924] has suggested a very useful outline of the classification of the cultivated rice and his plan could be tried in some countries with advantage. The ultimate aim of a natural classification in this particular species is to know the genetical make-up of each group and establishment of a number of heavy yielding pure line varieties. Some of the *Ngasein* varieties of Burma, *Phang-tien* variety of Indo-China and *Pinilig danid* of the Philippines are examples of good pure line varieties established in these countries respectively.

It is possible to obtain some indications as to the land of origin of rice and its cultivation from the language of different countries. The Sanskrit word for rice is *dhanya*, *brechee*, or *salé*. The first name slightly modified to *dhan* is the common term now in use all over northern and eastern India, and the word is common in Hindi, Urdu, Bengali, Oriya and Assamese. In Western India the term *sali* is largely used. The different types of rices (early, late, deepwater, etc.) have different names all over India, and there are also distinct and different names for the several hundred varieties of rices. It is also interesting to note that the grain itself is called by one name when in the husk, by another freed from it, by a third one when fried, a fourth name when flattened or pressed, and by a fifth one when cooked. The wild rice has a different name in Sanskrit to distinguish it from the cultivated rice (e.g. *treena dhanya*, and *neebara*). These minute nomenclature points to the great antiquity of the grain and the knowledge of its cultivation in India must therefore be regarded as very old.

Outside India, rice was not known in early days. It was unknown to the old Greeks and Romans and therefore they had no suitable term for this grain. It seems that Arabs were the first to know about rice from the Indians. They called it *arus*, or *ruz*. After the Arabian conquest of Spain rice was introduced to that country and the Spanish name *arroz* was evidently adapted from the arabic word. About this time the Greeks of the lower empire came to know about this crop from the Arabs, and the term *oruza*, which the Greeks gave, was nothing but a modification of the Arabic word *arus*. The generic name *Oryza* came from this Greek word. From these two sources, *i.e.* Spain and Greece, the knowledge of rice difinitely entered other European countries, as we find that the Italian name for rice is *riza* or *rizo*, German *reis*, French *riz*, and English *rice*.

It appears that the knowledge of rice cultivation reached Persia by direct route from South India. It is well known that maritime trade relationship existed between South India and the ports in the Persian Gulf. That the Persians obtained rice from South India is evident from the fact that it is called by the same name (*sali*) in Persia as in the South India. The source of rice cultivation in Java is also perhaps traceable to South India, as the grain is called *slawi* in Java, which is probably a corruption of *sali*.

The above philological note does give some idea as to the origin and the migration of its cultivation of this very old crop. It has been suggested by some ethnologists that the knowledge of rice must have entered Egypt very early in its history, as the Egyptians could not have constructed the gigantic pyramids unless they had this cereal as their food. This equally holds good for wheat also.

DISTRIBUTION: Native of India and Indo-China but cultivated throughout the warmer parts of Asia, S. Europe; Australia; Africa; Central and South America.

19. O. SATIVA *Linn.* var. FATUA *Prain* in Beng. Pl. **2**, 1184 (1903); Bor in Fl. Assam 5, 171 (1940).
O. sativa Linn. var. *bengalensis* Watt. Dict. Econ. Prod. Ind **5**, 504 (1891).
O. fatua Koen. var. *longiaristata* Ridley in Fl. Mal. Penin. **5**, 252 (1925).
O. fatua Koen. in Mem. Acad. Imp. Sc. Peters. Ser. 6, v. pt. 2, 177 (1840) *nomen.*

This is the wild rice of Asia. The name *O. sativa* Linn var. *fatua* Prain is provisionally adopted here on account of the difficulty of ascertaining the correct specific name which has been discussed under domestication of wild rice (Chatterjee l.c.). The plant needs a specific status.

DISTRIBUTION: India, Burma, Siam, Malay, Cochinchina, Malayasia.

20. O. SCHLECHTERI *Pilger* in *Engl. Jahrb.* **52**, 168 [1914]: Prodoehl in *Bot. Arch.* **1**, 234 (1922) Roschev l.c. 89: A. Cheval. in *Rev. Bot. Appl. et Agric. Trop.* **12**. 1024 (1932).

DISTRIBUTION: New Guinea.

21. O. STAPFII *Roschevicz* in *Bull. Appl. Bot. Genet. Pl. Breed.* **27**, Part 4, 51 (1931): A. Cheval. in *Rev. Bot. Appl. et Agric. Trop.* **12**. 1016 (1932);
O. silvestris Stapf. ex A. Cheval in *Bull. Mus. Hist. Nat.* Paris **16**. 405 (1910) *nomen.*

DISTRIBUTION: West Tropical Africa.

22. O. SUBULATA *Nees* in Agrost Bras. **2**. 518 (1829): Steud. *Pl. Glum* **1**, 3 (1853); Doell in Mart. Fl. *Bras.* 2, pt. **2**, 8 (1871); *Prod. Bot.* Archiv **1**, 232 (1922);
O candata Nees ex Doell in Mart. Fl. *Bras.* **2**. pt. 2,8 (1871) *nomen.*

DISTRIBUTION: South America: Brazil. Paraguay, Uruguay.

23. *O.* TISSERANTI *A. Cheval.* in Rev. *Bot. Appl. et Agric. Trop.* **12**. 1024 (1932).

DISTRIBUTION: Central Africa.

ORYZA Linn. (Synonymy)
ALTA *Swallen*
abromeitiana Prod.=O. MEYERIANA (*Zoll. et Mor*). *Baill.*
aristata Blanco=O. SATIVA Linn.
AUSTRALIENSIS *Domin.*

barthii A. Cheval.=O. PERENNIS *Moench* p.p.
BRACHYANTHA *A. Cheval. et Roehr.*
BREVILIGULATA *A. Cheval et Roehr.*
caudata Nees ex *Doell*=O. SUBULATA *Nees.*
ciliata Buch-Ham. ex Wall.=LEERSIA HEXANDRA *Sw.*
clandestina A. Br. ex Achers.=LEERSIA ORYZOIDES (Linn.) Sw.
COARCTATA *Roxb.*
communissima Lour=O. SATIVA *Linn.*
denudata Desv. ex Steud.=O. SATIVA *Linn.*
dewildemani Vanderyst=O. PERENNIS *Moench.*
EICHINGERI *Peter*
emarginata Steud=O. SATIVA *Linn.*
fatua Koen. *nomen*=O. SATIVA *Linn.* var. *fatua Prain.*
filiformis Buch-Ham. ex Steud.=O. GRANUTALA *Nees et Arn. ex Hook. f.*
GLABERRIMA *Steud.*
glumaepatula Steud=O. SATIVA *Linn.*
glutinosa Lour.=O. SATIVA *Linn.*
GRANDIGLUMIS (*Doell*) *Prod.*
GRANULATA *Nees et Arn. ex Hook. f.*
guineensis A. Cheval.=O. BRACHYANTHA *A. Cheval. et Roehr.*
hexandra Doell=LEERSIA HEXANDRA *Sw.*
LATIFOLIA *Desv.*
leersioides Baill=POTAMOPHILA LEERSIOIDES *Benth.*
leersioides Steud=POTAMOPHILA LEERSIOIDES *Benth.*
longistaminata A. Cheval. et Roehr.=O. PERENNIS *Moench.*
manilensis Merrill=O. MINUTE *Presl.*
marginata Desv. ex Steud.=O. SATIVA *Linn.*
mexicana Doell=LEERSIA HEXANDRA *Sw.*
MEYERIANA (*Zoll. et Mor.*) *Baill.*
mezii Prod.=O. BREVILIGULATA A. *Cheval. et Rochr.*
MINUTA *Presl.*
monandra Doell=LEESIA MONANDRA *Sw.*
montana Buch-Ham. ex Wall. *nomen*=O. OFFICINALIS *Wall. ex Watt.*
montana Lour.=O. SATIVA *Linn.* (wild form).
mutica Steud.=O. SATIVA *Linn.*
nepalensis G. Don ex Steud.=O. SATIVA *Linn.*
OFFICINALIS *Wall. ex Watt.*
oryzoides Brand=LEERSIA ORYZOIDES (*Linn.*) *Sw.*
oryzoides Dalla Torre et Sarnth=LEERSIA ORYZOIDES (Linn) *Sw.*
palustris Salisb.=O. SATIVA *Linn.*
parviflora Baill.=POTAMOPHILA PARVIFLORA *R. Br.*
parviflora P. Beauv.=O. SATIVA *Linn.*
PERENNIS *Moench.*
PERRIERI *A. Camus.*
platyphylla Schult. f.=O. LATIFOLIA *Desv.*
praecox Lour.=O. SATIVA *Linn.*
prehensilis Steud.=POTAMOPHILA PREHENSILIS *Benth.*
pubescens Steud.=O. SATIVA *Linn.*
pumila Hort. ex Steud=O. SATIVA *Linn.*
PUNCTATA *Kotschy ex Steud.*
repens Buch Ham. ex Steud.=O. SATIVA *Linn.*
RIDLEYI *Hook. f.*

rubra Hort=*Panicum colonum*=ECHINOCHLOA COLONUM (Linn.) Link.
rubribarbis Steud.=O. SATIVA *Linn.*
rufipogon Griffith=O. SATIVA *Linn.* (Wild form).
SATIVA *Linn.*
SCHELECHTERI *pilger.*
schweinfurthiana Prod.=O. PUNCTATA *Kotschy. ex Steud.*
segetalis Russ. ex Steud.=O. SATIVA *Linn.*
sorghoidea Steud=O. SATIVA *Linn.*
sorghoides Desv. ex Steud.=O. SATIVA *Linn.*
STAPFII *Roschev.*
Stenothyrsus K. Schum.=O. RIDLEYI *Hook. f.*
SUBULATA *Nees.*
TISSERANTI *A. Cheval.*
triandra Heyne ex Steud=O. GRANULATA *Nees et Arn. ex Hook. f.*
triticoides Griffith=O. COARCTATA *Roxb.*

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Prain, D. (1903). *Bengal Plants* **2**, 1184
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Rossberg, G. (1936). Doctorate Thesis, University of Berlin 1935 ; reviewed by C. E. Hubbard in *J. Bot.* **74**, 143
Roscheviez, R. J. (1931). *Bull. Appl. Bot. Genet. and Pl. Breed.* **27**, 3-133
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REVIEW

THE EVOLUTION OF GOSSYPIUM AND THE DIFFERENTIATION OF THE CULTIVATED COTTONS

By J. B. Hutchinson, R. A. Silow and S. G. Stephens

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THE production of commodities of high quality and in larger quantities with a view to ensuring a higher degree of self-sufficiency in regard to them occupies undoubtedly an important place of priority in the post-war programmes of reconstruction of the different countries of the world. However, success in attaining the targets in view, largely depends on the availability of improved types and high yielding strains of crops, capable of being cultivated over large areas. Intensive crop breeding based on a thorough understanding of all aspects of each individual crop, therefore, constitutes the most important link between the demand and supply. Comprehensive studies in the fields of taxonomy, genetics, cytology, agronomy, distribution, etc., form an essential prerequisite for the understanding of any crop. No other single institution has perhaps contributed in modern times so much to the advancement of fundamental knowledge of so difficult a crop as cotton with its world-wide distribution and panorama of forms or species, as the Cotton Research Station at Trinidad which was established by the Empire Cotton Growing Corporation in 1926. The programme of the Genetics Department of this Station included a very extensive and intensive study from living material of the genus *Gossypium*. The closing of the Trinidad station is now the occassion for a review of the work carried out there.

The evolution of *Gossypium* and the differentiation of the cultivated cottons by J. B. Hutchinson, R. A. Silow and S. G. Stephens, well-known workers in the field of cotton research, embodies, as is stated, a review of the genus as a whole and an account of its evolution and present status which is sufficiently broad-based on experimental evidence to be generally acceptable to cotton workers, and which fulfils the primary aim of the Genetics Department of providing an adequate foundation of knowledge for the proper planning of cotton breeding work. There is no gainsaying the fact that the publication records a great advance in our knowledge of the genus *Gossypium* and it serves not only as a guide for the successful planning of crop research covering the whole of the crop plant genus, but also as an excellent basis for the cotton botanist to formulate his programme of synthesis of economic characters.

The book is divided into four parts. The first entitled 'the classification of the genus *Gossypium*' is the work of Hutchinson. He has given a classification of the genus *Gossypium* based on genetic and cytological data which is simple, reasonable and comprehensive. The genus has been classified into eight species, groups or sections (1) Sturtiana, (2) Erioxyla, (3) Klotzschiana, (4) Thurberana, (5) Anomala, (6) Stocksiana, (7) Herbacea and (8) Hirsuta.

In connection with the discussion on the differentiation of the *arboreum* species, the author has, owing to lack of information, made no formal taxonomic sub-division of *G. arboreum* but has accepted Silow's six geographical races as representing the best natural sub-division of the species. The collection, however, of sufficient data for the proper understanding of the *arboreum* species seems a great necessity.

The wagad type (in the opinion of the authors of Part III) is a connecting link between the Persian and Western Indian types of *herbaceum*. The inclusion of *Punctatum* and *Marie-galante* varieties of *hirsutum* is a new feature. The kidney cottons of the Brazilian forests and the wild types of *Darwinii* have been given varietal rank under *barbadense*.

Under the caption of 'the evolution of the species of *Gossypium*', which is the subject matter of the second part of the book, Hutchinson and Stephens have given an outline of the status of the wild species and of the major factors which governed the evolution of the present day cultivated

cottons of the old and new worlds from them. The study revealed that notwithstanding the distribution of the wild species in all the continents which extend into the subtropical region, they are characterized by low genetic variability, absence of geographical races and little tendency to spread. *Anomalum* was found to be the only species widely distributed and *G. harknessii* x *G. armourianum* the only interspecific cross giving fully fertile F_1.

The third part, coming from the pen of Hutchinson and Silow, embodies an account of the several factors that influenced the differentiation of the true cottons.

The available information as to the antiquity of the cultivated cottons seems to point to the Indus valley as the spot where cotton was first used but the cytogenetic data appear to be conclusive that the progenitors of the early cottons of the Indus valley must have been introduced from southern Arabia or north-eastern Africa. The measurable lint characters of the cotton used in the fabrics discovered at Mohenjo-Daro [3000 B. C.] were found to be within the range of the Indian cottons of the present day, making it certain that the evolution of lint had already been completed by then.

Coming to the origin of the new world cottons, it is stated that on cytological grounds and on the evidence of reproducibility of characters of the new world cottons in the hybrids derived from a cross between old world x *G. raimondii*, it is concluded that the new world cottons must have originated from the hybridization of an old world cotton with *G. raimondii*. The next problem that the authors set themselves to find is as to how the two parents came together, so that hybridization could take place. They do not accept the land bridge theory put forward by Harland. The alternative suggestion of the authors, that the wanderers from the ancient cultures of the old world must have planted their cottons (Asiatic) in north-western South America and that hybridization must have occurred there—the cultivated Asiatic serving as the female and wild American, *G. raimondii*, as the male, is of absorbing interest. On the question as to whether the Asiatic cotton was of *arboreum* or *herbaceum* origin, Hutchinson and Silow concluded that the only diploid species that could have been carried across the Pacific to western South America was *G. arboreum* or a species ancestral to it.

The authors conclude the part by drawing attention to the need for a comprehensive study of the measurable characters of cotton lint. They expect that such a study of the modern cottons together with an examination of material from the fabrics of ancient India and Peru would largely elucidate the history of the development of quality in cotton.

Hutchinson and Stephens have, in the fourth part, dealt with the significance of *Gossypium* in evolutionary studies.

The distribution of the centres of variability of the more important genera of crop plants is stated to illustrate the intimate association that existed between the rise of human civilization and the development of crop plants. The distribution of variability in the crop plant genera common to both hemispheres is another point adduced in support of the theory of trans-Pacific rather than an Artic link between them. The authors further go on to say that the Indian centre is characterized by a heavy preponderance of plants reproduced by seed, whereas the Indo-Malayan plants are vegetatively propagated. They infer that since none of the Indo-Malayan plants—not even the cocoanut—has been established in the new world long enough to have developed centres of variability, it is evident that the trans-Pacific migration was carried out by people in direct contact with India and not by a race long established in Indo-Malaya.

The authors conclude that the outstanding feature of the discussion of differentiation in *Gossypium* has been the importance of variability and despite the need for uniformity in the product to meet market requirements, future programme must be designed for the maintenance of variability rather than for the isolation of pure lines.

The book contains at the end a comprehensive bibliography and indices which make it easy of reference.

Literature on crop botany contains perhaps few such publications of specialized studies on a single genus, which have thrown a flood of light on the origin and differentiation of species and have

enabled a clearer understanding of the genetic make-up of the present varieties. The 141 pages of this book are studded with valuable information.

The conclusion seems inevitable that crop research which aims at high targets in respect of economic characters of a crop should not fight shy of the investigation of the fundamental problems but should be planned on as wide a basis as possible so as to include within its scope the integration of specialist sciences.

This book should be read by all botanists and agricultural workers, whatever be the crop or branch of science they have specialized in.[K. D.]

PLANT QUARANTINE NOTIFICATION

Notification No. F. 9-72/47=PPA, dated the 23 January 1948, of the Government of India in the Department of Agriculture

SOME of the new insecticides that have achieved much popularity during recent years have been given various proprietory trade names by manufacturers in U. S. A., England and Europe, which has led to a great deal of confusion in recording the results of experiments. For instance, 'Dichloro-diphenyl-trichlorethane' has received universal recognition under the contracted name D.D.T., but 'Hexachlorocyclohexane' otherwise known as Benzene Hexachloride, has been called by different trade names *e.g.*, '666', 'Gammexane', etc.

In view of the desirability of having a uniform nomenclature throughout the world, the Research and Development Co-ordinating Committee on Insecticides of the British Agricultural Research Council recently decided to advise that this insecticide should be known by the abbreviation 'B. H. C.' as this proposal has received approbation not only in England but also in India and U. S. A., it is suggested that entomological workers in India should refer to this insecticide as 'B. H. C.'. If reference is to be made to its different isomers, the *Alpha*, *Beta*, *Gamma* and *Delta* isomers should be called α B. H. C., β B. H. C., γ B. H. C. and δ B. H. C. The proprietory name 'Gammexane' (I. C. I.) will, of course, be referable only to the *Gamma* Isomer of B. H. C.

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In view of the desirability of having a uniform nomenclature throughout the world, the Research and Development Committee (Insecticides) of the British Agricultural Research Council recently decided to advise that this insecticide should be known by the abbreviation "B. H. C." as this proposal has received approval not only in England but also in India and U. S. A. It is suggested that entomologists working in India should refer to this insecticide as "B. H. C." It is proposed to be made to the different forms, the Alpha, Beta, Gamma and Delta isomers should be called a B. H. C., β B. H. C., γ B. H. C. and δ B. H. C. The proprietory name "Gammexane" (1, 2, 3, 4, 5, 6 trichlorocyclohexane) will, of course, be referable only to the Gamma Isomer of B. H. C.

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The Editorial Board, in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

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Articles intended for The Indian Journal of Agricultural Science should be accompanied by short popular abstracts of about 330 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged alphabetically according to author's names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initial), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets, when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state ' Original not seen '.

Sources of information should be specifically acknowledged.

As the *format* of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{8}$ in. $\times$ $9\frac{5}{8}$ in. cut), no text figure, when printed, should exceed $4\frac{1}{2}$ in. $\times$ 5 in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{3}{4}$ in. $\times$ 8 in. exclusive of that for letter press printing.

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